QUALITY EVALUATION LABORATORY
UNITED STATES NAVAL AMMUNITION DEPOT
CRANE, INDIANA

EVALUATION PROGRAM FOR NICKEL CADMIUM SEALED CELLS

GENERAL PERFORMANCE TEST OF GENERAL ELECTRIC COMPANY 12.0 AMPERE HOUR CELLS

QE/C 64-6 8 APRIL 1964

PREPARED UNDER THE DIRECTION OF

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Enclosure (1)

QE/C 64-6

REPORT BRIEF

SEALED NICKEL CADMIUM BATTERY PROGRAM

OF

CELLS DESIGNED FOR USE IN SPACECRAFT

Ref: (a) National Aeronautics and Space Administration Purchase Order Number W11,252B
(b) NASA ltr BRA/VBK/pad of 25 September 1961 w/BUWEPS first end FQ-1:WSK of 2 October 1961 to CO NAD Crane
(c) Preliminary Work Statement for Battery Evaluation Program of 25 August 1961
(d) National Aeronautics and Space Administration Preliminary Specification "Environmental Exposures and Tests for Subassemblies of International Ionosphere Satellite S-51" of 7 February 1961
(e) MIL-E-5272C(ASG) Amendment 1

I. TEST ASSIGNMENT BRIEF.

A. In compliance with references (a) and (b), evaluation of Sealed Nickel Cadmium Cells was begun according to the program outline of reference (c). References (d) and (e) are Environmental Test Specifications.

B. The object of this evaluation program is to gather specific information concerning sealed nickel cadmium cells designed for use in spacecraft. Information concerning the performance characteristics and limitations, including cycle life under various electrical and environmental conditions, will be of interest to power system designers and users. Cell weaknesses, including causes of failure of present designs, will be of interest to suppliers as a guide to product improvement.

C. A total of 1100 cells was purchased by National Aeronautics and Space Administration (NASA) from four manufacturers, and consist of seven sample classifications ranging from 3 to 20 ampere hours.

D. The program is divided into three main sections consisting of Acceptance Tests, General Performance Tests and Cycle Life Tests.

E. This report is the sixth of a series of seven of the General Performance Test Section. It gives the results of the characterization tests of five 12 ampere hour size cells supplied by the General Electric Company, Gainsville, Florida. These cells are rated at 12.0 ampere hours by the manufacturer.

II. SUMMARY OF RESULTS.

A. The cells were capable of withstanding the Vibration, Mechanical Shock, and Acceleration requirements.

B. Temperatures below and above 25° C. imposed the primary limitations on the charge acceptance and the discharge capacity of the cells.

1. At 25° C. the on charge voltage never reached the maximum limit of 1.50 volts/cell at either the c/10 or c/5 charge rate. A comparison of the discharge capacities show that the discharge capacity at the c/5 rate, when preceded by a charge at the c/10 rate was about 12 percent higher than when preceded by a charge at the c/5 rate. However, at the c/2 rate, the discharge capacities when preceded by either the c/10 or c/5 rate were equal.

2. At 0° C. the on charge voltage reached the maximum limit of 1.50 volts/cell at about 75 percent of the charging period on all of the recharges at the c/10 rate and on about 80 percent of the recharges at the c/5 rate. The capacities at the c/2 discharge rate, when preceded by charge rates of c/10 and c/5 averaged 3.2 percent and 4.6 percent respectively over their average capacities at 25° C. Similarly, the capacity at the c/5 rate, when preceded by a charge at the c/10 rate, averaged 2.5 percent over the capacity measured at 25° C. However, the capacity at the c/5 rate, when preceded by a charge at the c/5 rate, although comparable to the other capacities measured at 0° C., averaged 14.6 percent more than when measured at 25° C.

3. At 50° C. the on charge voltage never reached the maximum limit of 1.50 volts/cell. The charge rate in combination with discharge rates appeared to have an additional or secondary influence on the discharge capacity of the cells. The capacities of the cells measured at the c/5 rate averaged eight percent less when previously charged at the c/5 rate than when previously charged at the c/10 rate. Likewise, the capacities of the cells measured at the c/2 rate averaged seven percent less, when previously charged at the c/5 rate, than when previously charged at the c/10 rate. The inefficiency of charge acceptance at the c/10 and c/5 rates limited the capacities at the c/5 rate to 48.8 and and 49.9 percent respectively of the 25° C. capacities. Likewise, the inefficiency of charge acceptance at the c/10 and c/5 rates limited the capacities at the c/2 rate to 44.3 and 40.9 percent respectively of the 25° C. capacities.

C. The cells at 0° C. were incapable of accepting a continuous overcharge at a rate of c/10 or higher as a maximum on charge voltage limit of 1.55 volts/cell was reached prematurely. Indications are that, at 25° C., the cells are capable of withstanding overcharges up to the c/2 rate although two of the cells did function at the c/1 rate. Indications are that, at 50° C., the cells are capable of withstanding overcharges at

the c/2 rate although four of the five cells functioned at the c/1 rate. One cell was discontinued at the c/1 rate because of rapid increase of cell temperature which may have indicated the first stage of thermal runaway. These high rate overcharges were accomplished during the overcharge sequence which began with the c/10 rate and was increased by steps to the c/1 rate, after stabilization of voltage at each preceding charge rate. It is questionable whether the cells could have been overcharged beyond the c/10 rate when applied initially to a fully charged cell, without reaching the maximum voltage limit of 1.55 volts/cell before voltage stabilization.

D. Charging efficiency was limited by temperature.

1. At 0° C. the voltage limit of 1.50 volts/cell was reached at each charge rate at approximately the "knee" of the curve with the exception of the two cells at the c/1 rate that limited before the "knee" was reached. The maximum capacity of all cells at all charging rates ranged from 74 to 113 percent of their actual capacities of the acceptance tests at 25° C.

2. At 25° C. the voltage limit was reached at the c/5 and c/1 charge rates before the "knee" of the curve was reached. At the c/24, c/16 and c/10 charging rates, the maximum discharge capacity was reached at approximately 100 to 125 percent of the rated capacity recharge. When preceded by the c/5 and c/1 charge rates, the maximum capacity was reached at approximately 250 percent of the rated capacity recharge. The maximum capacity of the cells, in percentage of the acceptance test capacities, following each of the charge rates, ranged from 55 percent following the c/24 charging rate to 110 percent following the c/5 charging rate.

3. At 50° C. the voltage limit of 1.50 volts/cell was not reached at any of the charge rates. The inefficiency of the charge acceptance at 50° C. at all charging rates allowed a maximum discharge capacity, in percentage of acceptance test capacities at 25° C., of only 29 percent following the c/16 charging rate to 50 percent following the c/1 rate.

RESULTS OF GENERAL PERFORMANCE TESTS

OF

12.0 AMPERE HOUR SEALED NICKEL CADMIUM CELLS

MANUFACTURED BY

GENERAL ELECTRIC COMPANY

I. INTRODUCTION.

A. On 11 July 1963, this activity began the General Performance Tests on five cells, following completion of the acceptance tests of the 200 cells. The general performance tests were completed on 15 November 1963.

B. The five cells chosen for the general performance tests consisted of two with actual capacities above the average of the 200 accepted cells, one with capacity approximately equal to the average, and two with capacities below the average.

II. TEST CONDITIONS.

A. The general performance or characterization tests were performed at existing relative humidity and atmospheric pressure and at three specific temperatures. The tests and test temperatures were as follows:

1. Vibration Test at room ambient temperature.

2. Mechanical Shock Test at room ambient temperature.

3. Acceleration Test at room ambient temperature.

4. Charge and Discharge Voltage versus Time at 0° C., 25° C., and 50° C.

5. Overcharge Characteristics at 0° C., 25° C., and 50° C.

6. Charging Efficiency at 0° C., 25° C., and 50° C.

B. All charging was by modified constant current with a voltage limit. All discharges were constant current.

III. CELL IDENTIFICATION AND DESCRIPTION.

A. The five cells used for these tests were picked from the 200 cells on the acceptance test section. The capacity of cells 33-24 and 33-29 was above the average of the 200 cells, cell 11-7 approximated the average capacity and cells 4-16 and 4-20 were below the average capacity.

B. The 12.0 ampere hour cell is rectangular in shape with an average height (base to top of negative terminal), length and width of 4.59, 1.11 and 3.02 inches respectively. The average weight was 562.0 grams.

C. The cell container or can, and the cell cover are made of stainless steel. Both terminals are insulated from the cell cover by a ceramic seal and protrude as 1/4-20 threaded posts.

IV. TEST PROCEDURES AND RESULTS.

A. Sinusoidal Vibration Test.

1. Each cell, fully charged, was individually mounted in a rigid test fixture attached to the table of a M. B. Electronics Model C-10 vibrator. The amplitude or acceleration was monitored on the test fixture near the mounting points.

2. Each cell in turn, was then subjected to the sinusoidal vibration test conditions given in paragraph 3.2.4.1.2.1 of reference (d), which stated that the applied frequency shall be swept from the lowest to the highest frequency, once for each range and for each axis specified in the following schedule.

SINUSOIDAL SWEEP SCHEDULE

Frequency Range - cps	Test Time Minutes	Acceleration g, 0 - to - Peak
10 - 50	1.66	2.3 (a)
50 - 500	1.66	10.7
500 - 2000	1.00	21.0
2000 - 3000	0.30	54.0
3000 - 4500	0.36	21.0 (b)
	5.00 Min. Each Axis	

NOTES: (a) Within maximum amplitude limit of vibration exciter.
(b) Within maximum frequency limit of vibration exciter.

3. During the applied vibration, the cells were discharged at a rate of c/5 amperes. The discharge current and terminal voltage were monitored for evidence of cell malfunction during applied vibration.

After the vibration test, the cells were visually examined for evidence of mechanical damage and checked by litmus paper for electrolyte leakage.

B. Random Motion Vibration.

1. Following the sinusoidal vibration, each cell was subjected to gaussian random vibration applied to each axis with the "g-peaks" clipped at three times the root-mean-square acceleration specified in the schedule. The vibration was applied successively to the Z-Z, X-X, and Y-Y axes. With the cell installed, the control accelerometer response was equalized with peak-notch filterization such that the specified power spectral density (PSD) values were within ± 3 db throughout the frequency band.

RANDOM VIBRATION SCHEDULE

Frequency Range cps	Test Duration Minutes	PSD Level g^2/cps	Approximate Acceleration g-rms
20 - 2000	4 Each Axis	0.07	11.5 (a)

NOTE: (a) Within amplitude limit of vibration exciter.

2. There were no failures of the five cells subjected to the vibration tests.

C. Mechanical Shock Test.

1. Each cell was charged at the c/10 rate for 16 hours following the vibration test.

2. Each fully charged cell was mounted in a rigid test fixture. The fixture and the cells were mounted on the Barry Type 16805 Shock Machine. Each cell was subjected to 18 impact shocks as outlined in Procedure V, paragraph 4.15.5.1 of Specification MIL-E-5272C(ASG), reference (e), except that 40 G (for 11 ± 1 milliseconds) was used in lieu of 15 G. Three shocks were applied in each direction of each of the three mutually perpendicular axes of the cells.

3. During the shock test, the cells were discharged at a rate of c/5 amperes. The discharge current and terminal voltage were monitored at the moment of impact for evidence of malfunction of any cells.

4. At the conclusion of the test, the cells were examined for mechanical damage and checked with litmus paper for electrolyte leakage.

5. There were no failures of the five cells subjected to the mechanical shock tests.

D. Acceleration Test.

1. Each cell was charged at c/10 rate for 16 hours following the mechanical shock test.

2. Each fully charged cell was mounted in a rigid fixture attached to the Genisco Model C-159 Centrifuge. The cell was then subjected to the acceleration test conditions specified in paragraph 3.2.5.1.2 of reference (d). Accelerations were in the order listed below:

Axis Direction	Acceleration Gravity Units (G)	Duration Minutes
+Z	28.0	5.0
±Y +X	4.0	3.0
-X	12.0	0.5

3. During the acceleration tests, the cells were discharged at a rate of c/5 amperes. The discharge current and terminal voltage were monitored for evidence of cell malfunction during the acceleration test periods.

4. At the conclusion of the tests, the cells were examined for mechanical damage and checked with litmus paper for electrolyte leakage.

5. There were no failures of the five cells subjected to the acceleration tests.

E. Charge and Discharge Voltage Versus Time.

1. The five cells, each with a thermocouple attached to the positive terminal, were placed in a temperature chamber and allowed to stabilize at 0° C.

2. The five cells were subjected to the charge and discharge sequence listed below:

Charge	Discharge	No. of Cycles	Temperature	Data			Charge Voltage
c/10 - 16 Hrs	c/5 to 0.9 Volts	2**	0° C.	Voltage	Time	Cell* Temp.	Limited to 1.5 V/Cell
c/10 - 16 Hrs	c/2 to 0.9 Volts	2**	0° C.	Voltage	Time	Cell* Temp.	Limited to 1.5 V/Cell
c/5 - 8 Hrs	c/5 to 0.9 Volts	2**	0° C.	Voltage	Time	Cell* Temp.	Limited to 1.5 V/Cell
c/5 - 8 Hrs	c/2 to 0.9 Volts	2**	0° C.	Voltage	Time	Cell* Temp.	Limited to 1.5 V/Cell

* Cell temperature measured by thermocouple.

** Each cell was subjected to two or more charge-discharge cycles, until repeatability of data was satisfactory.

3. Upon completion of the above sequence, the tests were repeated for 25° C. and 50° C. ambient temperature conditions.

4. The results are shown graphically with cell charge and discharge voltages versus time as a function of rate of charge, rate of discharge and ambient temperature on Figures 1 through 20. Figure 21 is a graphic summary of the data of Figures 1 through 20.

5. There were no cell failures during any portion of these tests.

F. Overcharge Characteristics.

1. The five discharged cells were allowed to stabilize at 0° C. The cells were then subjected to the overcharge sequence listed below:

a. Charge at c/10 for 16 hours.

b. Charge at c/10 until the cell voltage stabilizes.

c. Charge at c/8 until the cell voltage stabilizes.

d. Charge at c/6 until the cell voltage stabilizes.

e. Charge at c/4 until the cell voltage stabilizes.

f. Charge at c/2 until the cell voltage stabilizes.

g. Charge at c/1 until the cell voltage stabilizes.

2. Upon completion of the above sequence, the tests were repeated for 25° C. and 50° C. ambient temperature conditions.

3. On all tests, the voltage limit was 1.55 volts per cell, and the cell temperature limit was 77° C. Exceeding either limit terminated the test at that temperature.

4. Table I shows the cell temperature as compared to the ambient temperature at the voltage stabilization point of each charging rate. Where "voltage limited" is noted, the cell voltages increased to the limiting value of 1.55 volts at the respective charging rate without reaching a stabilization point.

5. The results are shown graphically on Figure 22 as a plot of the cell voltage versus the log of the charging current.

6. There were three failures at the c/1 charge rate at 25° C. Cells 4-20, 33-24 and 33-29 experienced thermal runaway at the c/1 charge rate, shorted out internally, and bulged due to high internal pressure which broke the bolts holding the metal restrainers.

7. These three cells were replaced by cells 4-24, 11-11 and 33-5. The overcharge sequence at 50° C. was then run. Four of the five cells functioned at the c/1 rate. One cell was discontinued at the c/1 rate due to steadily increasing cell temperature.

G. Charging Efficiency.

1. At the completion of the overcharge characteristics sequence, the cells were discharged at the c/2 rate to 1.0 volt per cell.

2. The five cells were then divided into three groups as follows:

a. One group of two cells (one above average and one below average) to be tested at 0° C. ± 2° C.

b. One group of one cell (average cell) to be tested at 25° C. ± 2° C.

c. One group of two cells (one above average and one below average) to be tested at 50° C. ± 2° C.

3. At each temperature, the charging efficiencies of each of the five charging rates; c/40, c/24, c/16, c/5 and c/1; were determined by a series of charges at each given rate at designated increased time periods followed by discharges to 1.0 volt per cell until the charge ampere hours versus the discharge ampere hours indicated the "knee" had been reached and verified as shown in Figures 23 through 27. The duration of the initial charge at each rate was one-half of the number of hours required for 100 percent charge.

4. A normalizing cycle consisting of a c/5 charge for 8 hours and a c/2 discharge to 1.0 volt was given all cells after each set of charge rate tests before proceeding to the next series.

5. A sample run for the c/10 charging rate was as follows:

a. Recharged at c/10 for 5 hours.
Discharged at c/2 to 1.0 volt.

b. Recharged at c/10 for 6 hours.
Discharged at c/2 to 1.0 volt.

c. Recharged at c/10 for 7 hours.
Discharged at c/2 to 1.0 volt.

d. Recharged at c/10 for "X" hours.
Discharged at c/2 to 1.0 volt.

NOTE: X = number of hours necessary to indicated that the "Knee" of the Charge Ampere Hours versus Discharge Ampere Hours has been reached.

APPENDIX

I. Table I shows the cell temperatures as compared to the ambient temperatures at the stabilizing point of each charging rate.

II. FIGURES.

A. Figures 1 through 20 are graphs showing charge and discharge voltages versus time as a function of rate of charge, rate of discharge and ambient temperature.

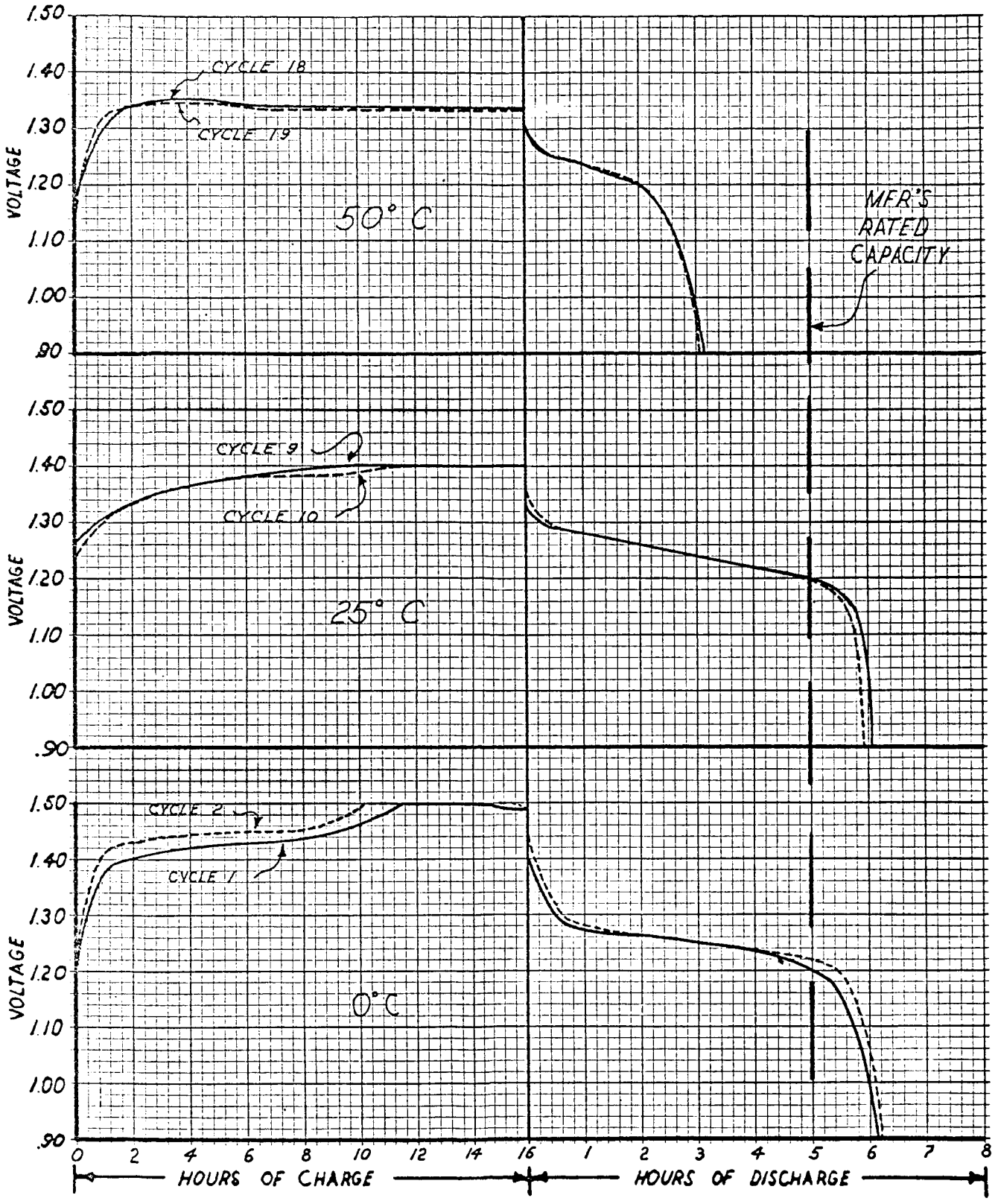
B. Figure 21 is a graphic summary of the data of Figures 1 through 20.

C. Figure 22 is a graph showing overcharge characteristics.

D. Figures 23 through 27 are graphs showing the charging efficiencies as a plot of charging ampere hours versus discharging ampere hours.

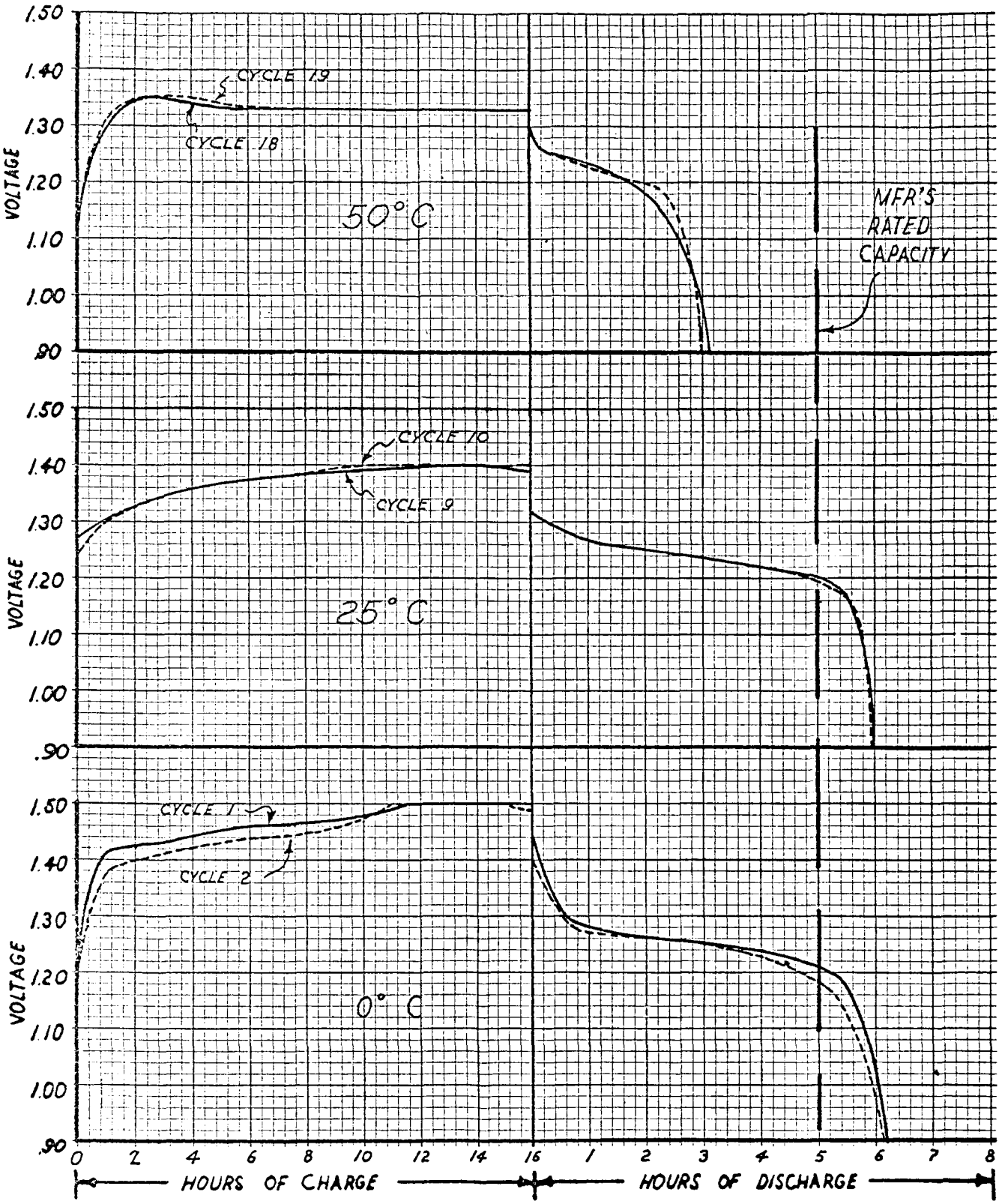
TABLE I

Cell Number	Ambient Temperature	Stabilizing Temperature (° C.) c/10 Charge	c/8 Charge	c/6 Charge	c/4 Charge	c/2 Charge	c/1 Charge
11-7	0° C.	- - - - - - - - - VOLTAGE LIMITED - - - - - - - - -					
33-24	0° C.	1.11	- - - - - - - VOLTAGE LIMITED - - - - - - -				
33-29	0° C.	- - - - - - - - - VOLTAGE LIMITED - - - - - - - - -					
4-20	0° C.	0.56	- - - - - - - VOLTAGE LIMITED - - - - - - -				
4-16	0° C.	- - - - - - - - - VOLTAGE LIMITED - - - - - - - - -					
11-7	25° C.	31.1	28.9	27.2	30.0	39.4	68.9
33-24	25° C.	32.2	30.6	29.4	33.3	46.1	Thermal Runaway
33-29	25° C.	32.2	30.6	29.4	34.4	47.8	Thermal Runaway
4-20	25° C.	32.2	30.6	30.0	35.0	47.8	Thermal Runaway
4-16	25° C.	32.2	30.0	28.9	32.2	43.3	71.1
11-7	50° C.	51.1	51.7	52.8	54.4	63.3	68.3
33-24	50° C.	51.1	52.8	54.4	57.8	63.9	71.1
33-29	50° C.	51.7	53.3	55.6	59.4	63.9	76.7
4-20	50° C.	51.1	52.8	53.3	56.1	60.6	65.6
4-16	50° C.	50.6	51.7	51.7	52.8	57.8	61.7



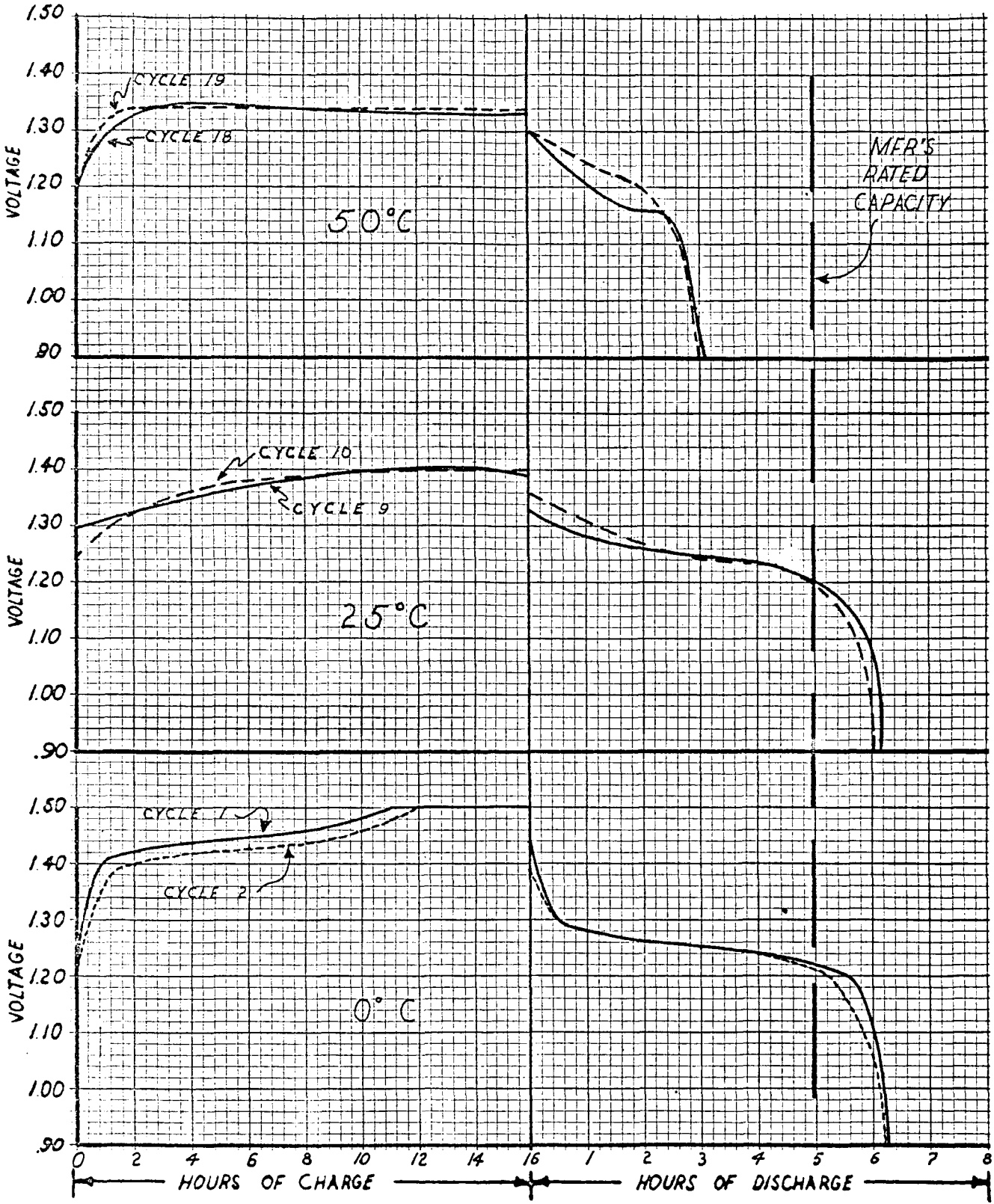
G.E. 12 A.H. CELL NO. 4-16 NAD CRANE CAPACITY 12.90 A.H.
CHARGE CURRENT 1.2 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 2.4 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 1



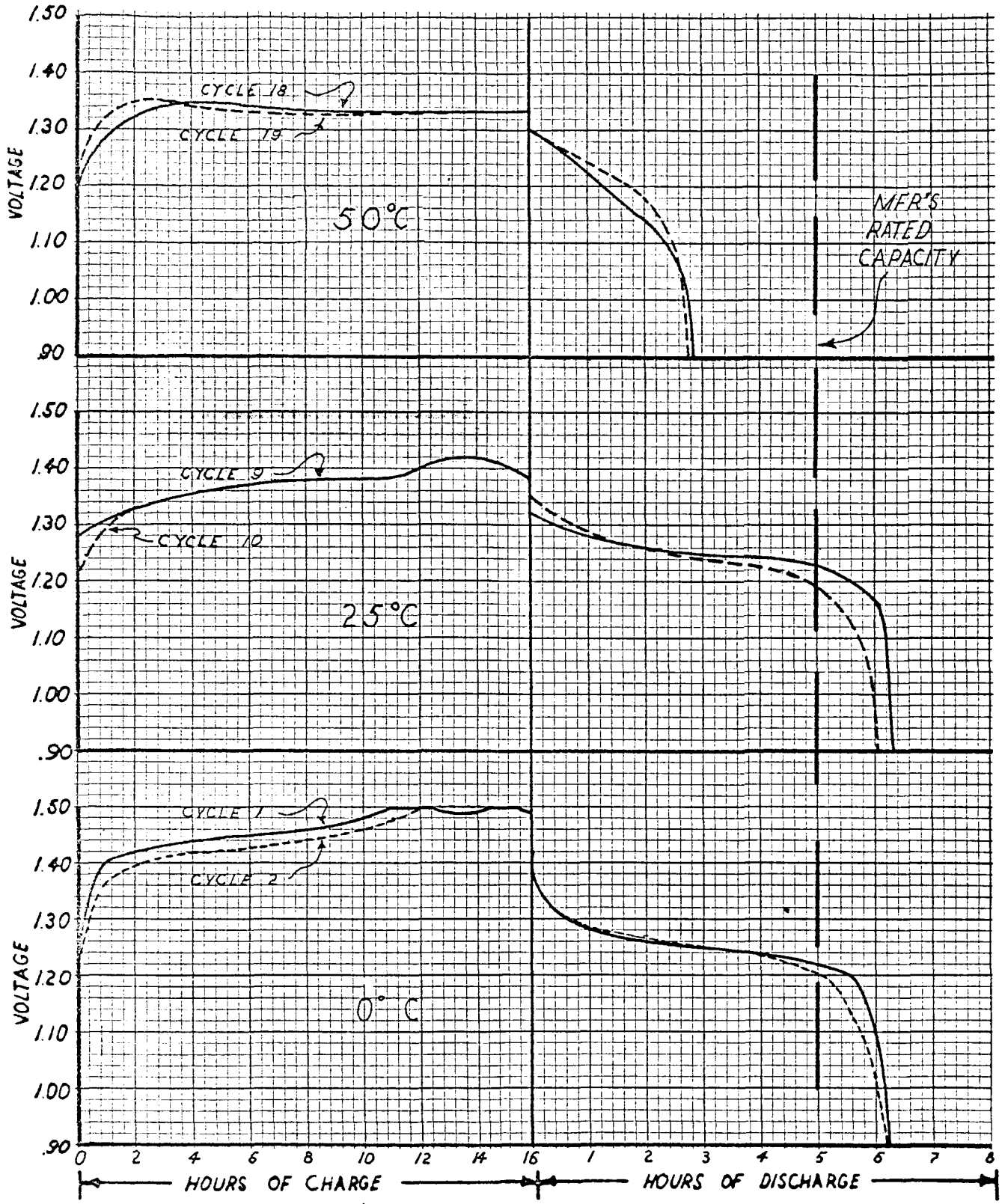
G.E. 12 A.H. Cell No. 4-20 NAD CRANE CAPACITY 12.90 A.H.
CHARGE CURRENT 1.2 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 2.4 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 2



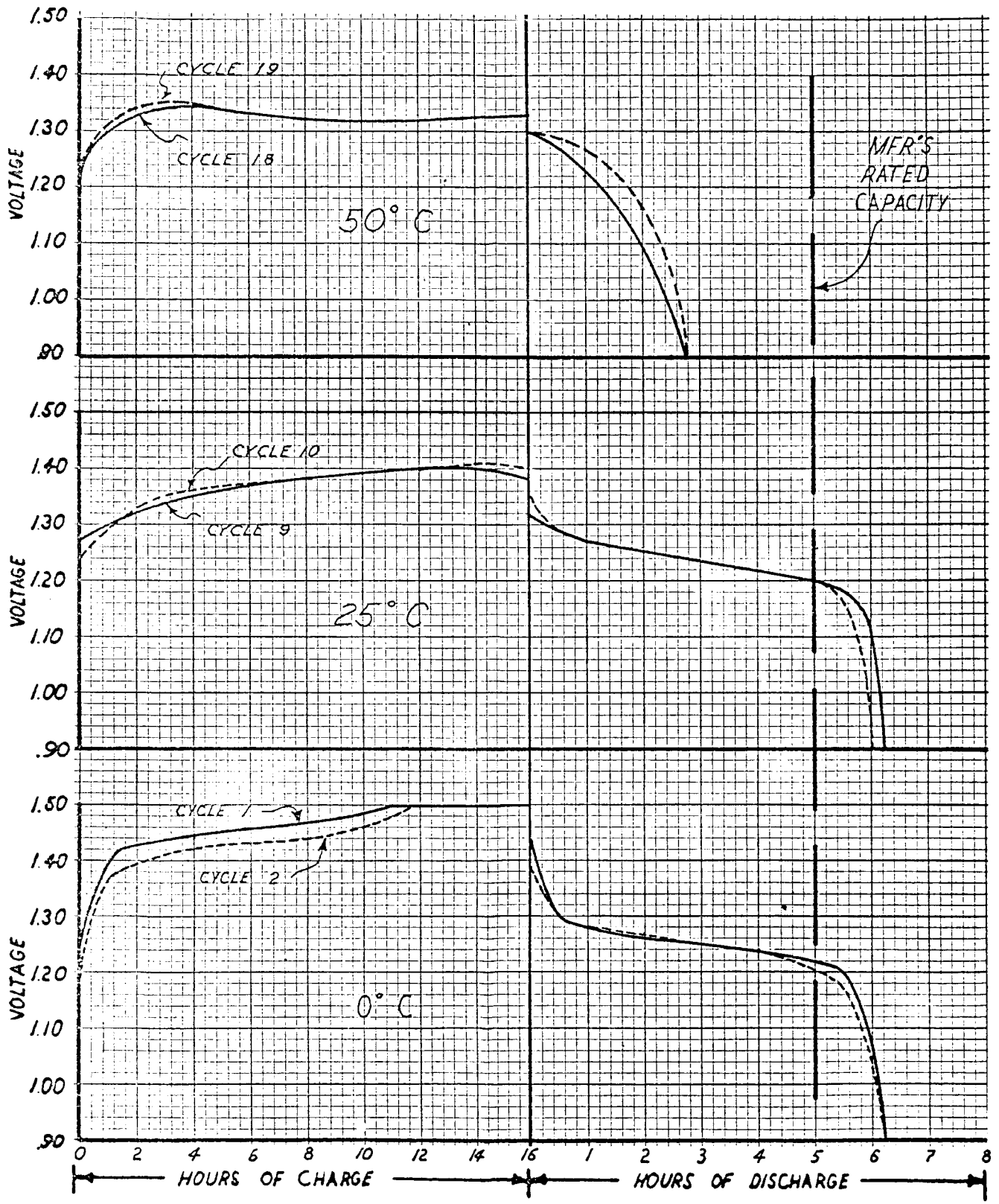
G.E. 12 A.H. CELL No. 11-7 NAD CRANE CAPACITY 14.52 A.H.
CHARGE CURRENT 1.2 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 2.4 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 3



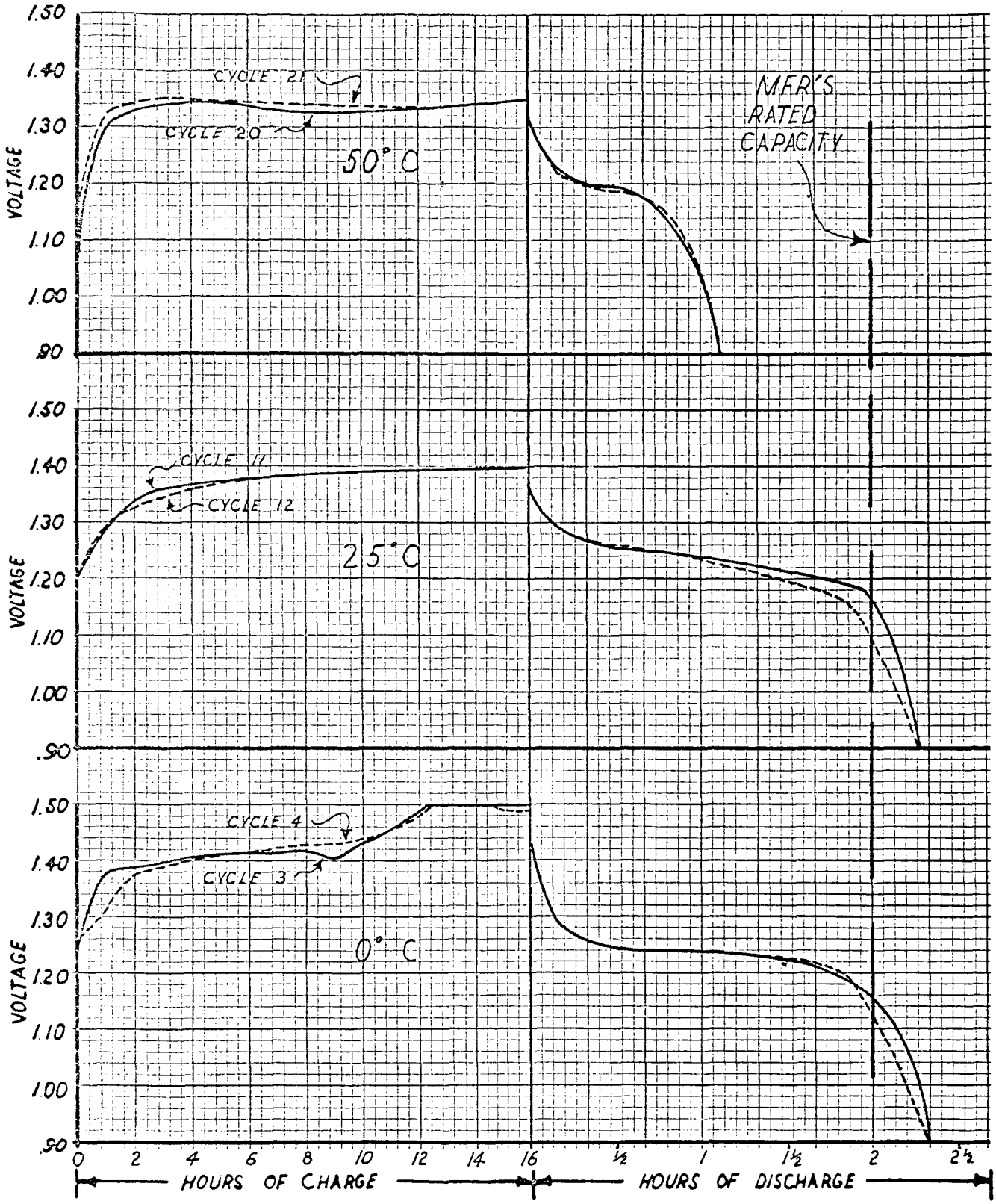
G.E. 12 A.H. Cell No. 33-24 NAD CRANE CAPACITY 15.60 A.H.
CHARGE CURRENT 1.2 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 2.4 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 4



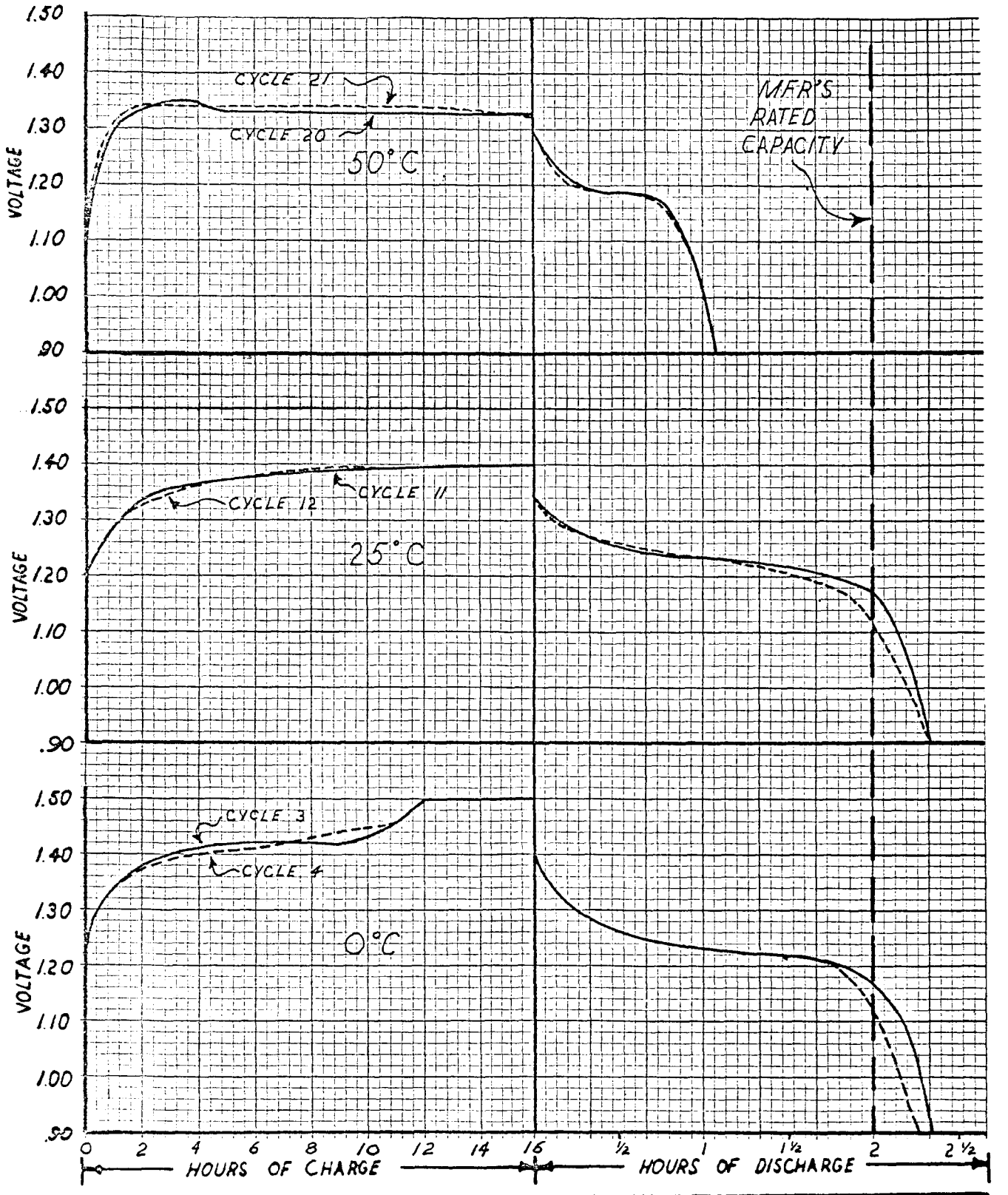
G.E. 12 A.H. CELL No. 33-29 NAD CRANE CAPACITY 15.60 A.H.
CHARGE CURRENT 1.2 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 2.4 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 5



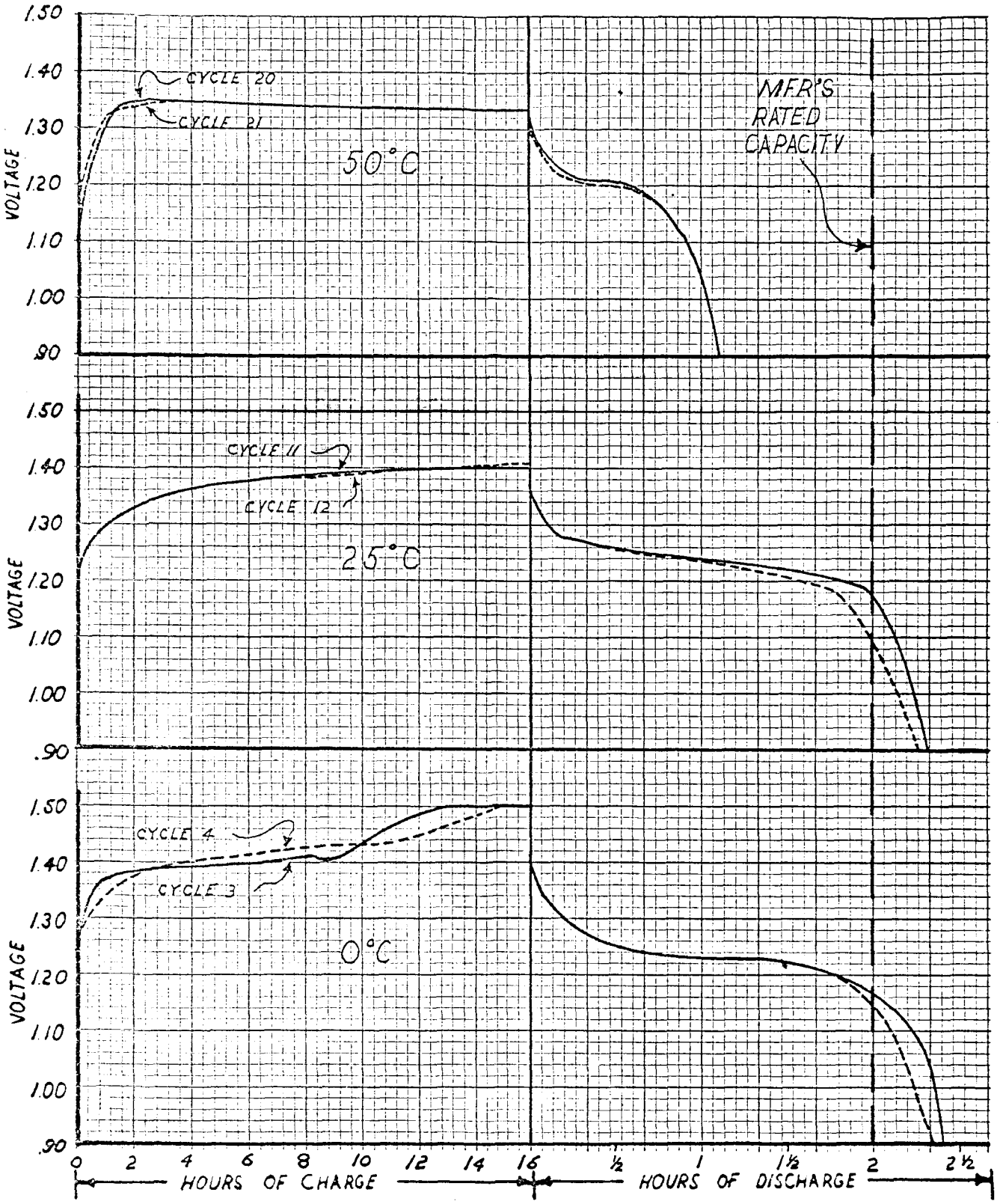
G.E. 12 A.H. Cell No. 416 NAD CRANE CAPACITY 12.90 A.H.
CHARGE CURRENT 1.2 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 6.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 6



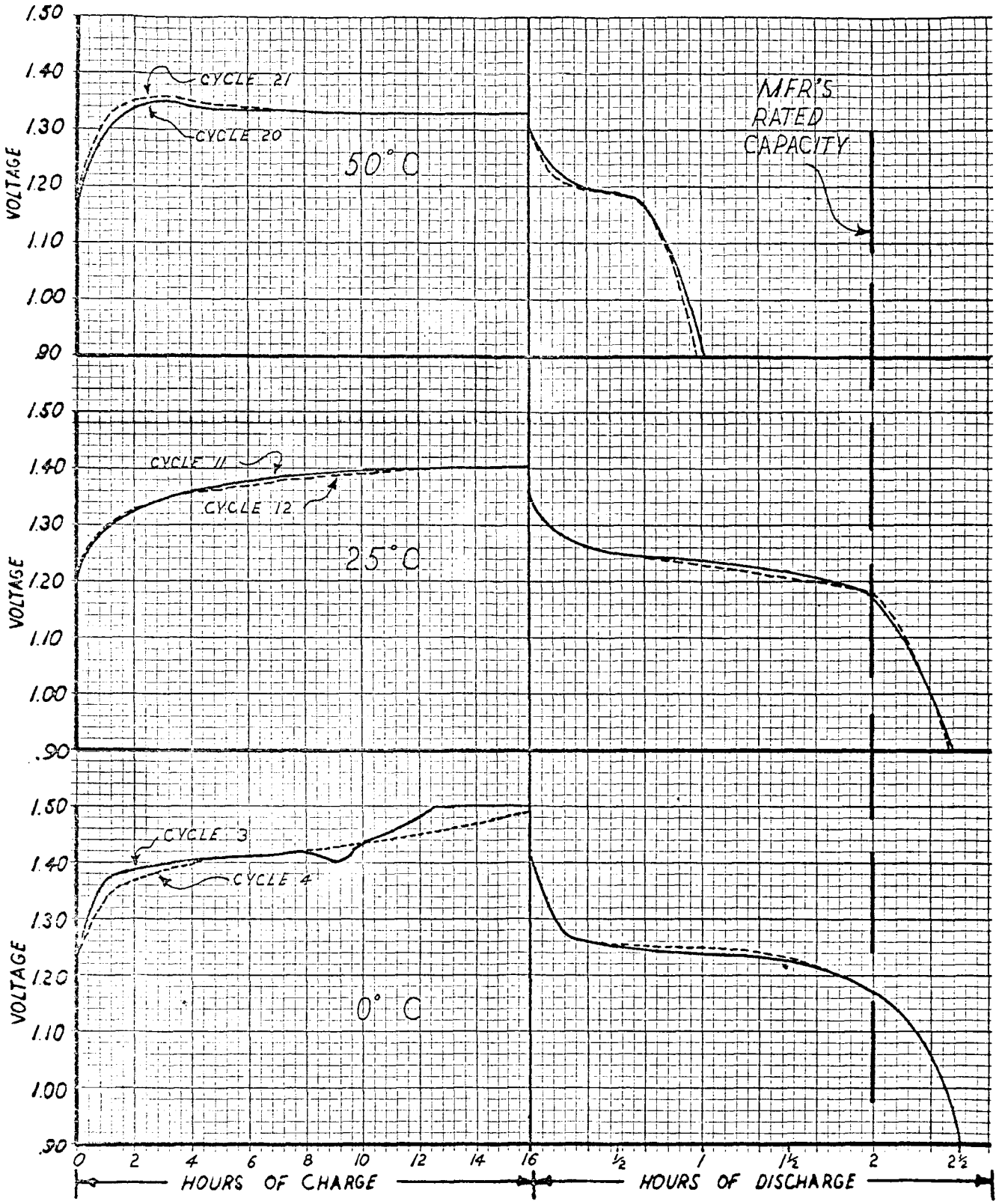
G.E. 12 A.H. CELL No. 420 NAD CRANE CAPACITY 12.90 A.H.
CHARGE CURRENT 1.2 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 6.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 7



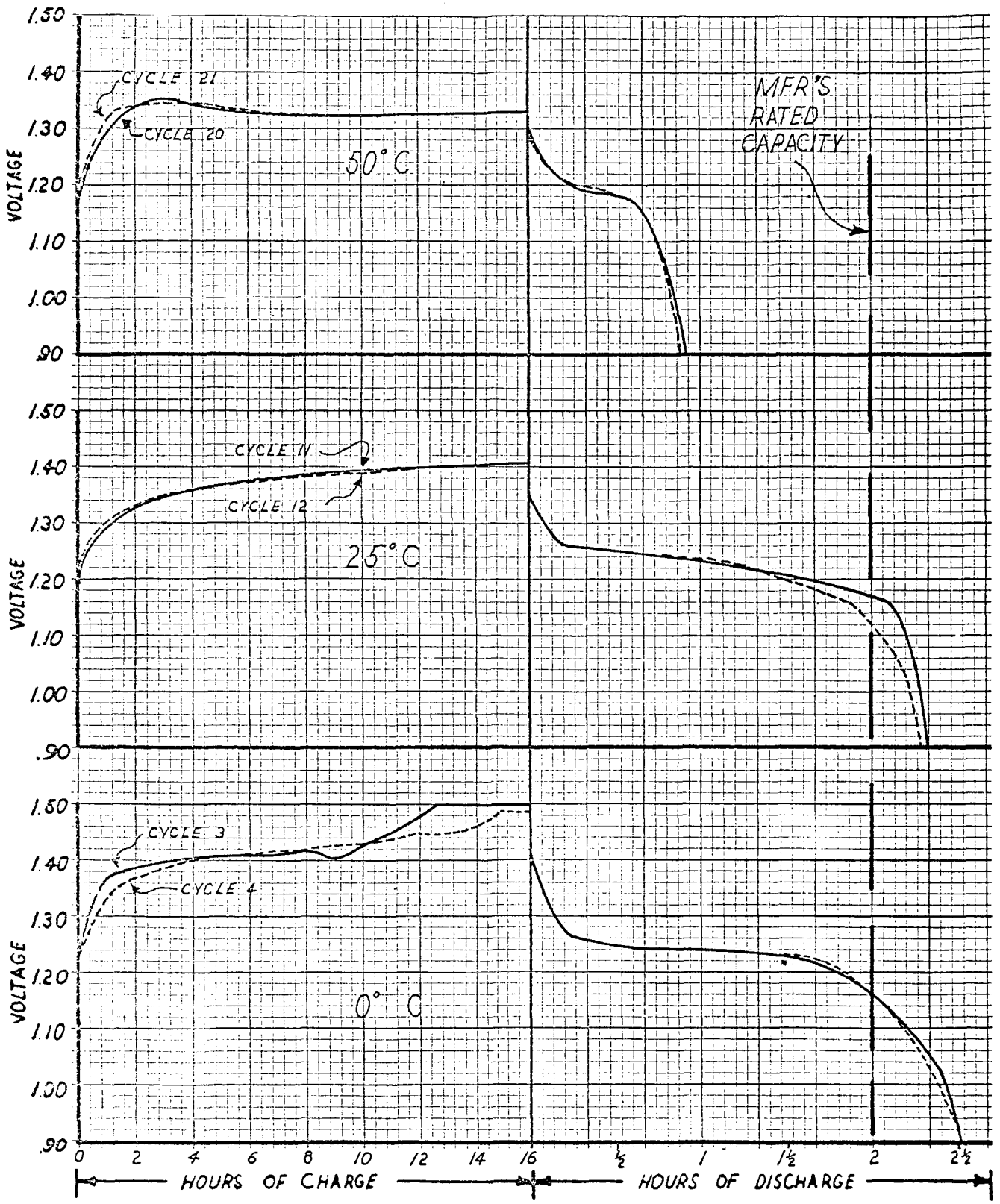
G.E. 12 A.H. CELL NO. 11-7 NAD CRANE CAPACITY 14.52 A.H.
CHARGE CURRENT 1.2 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 6.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 8



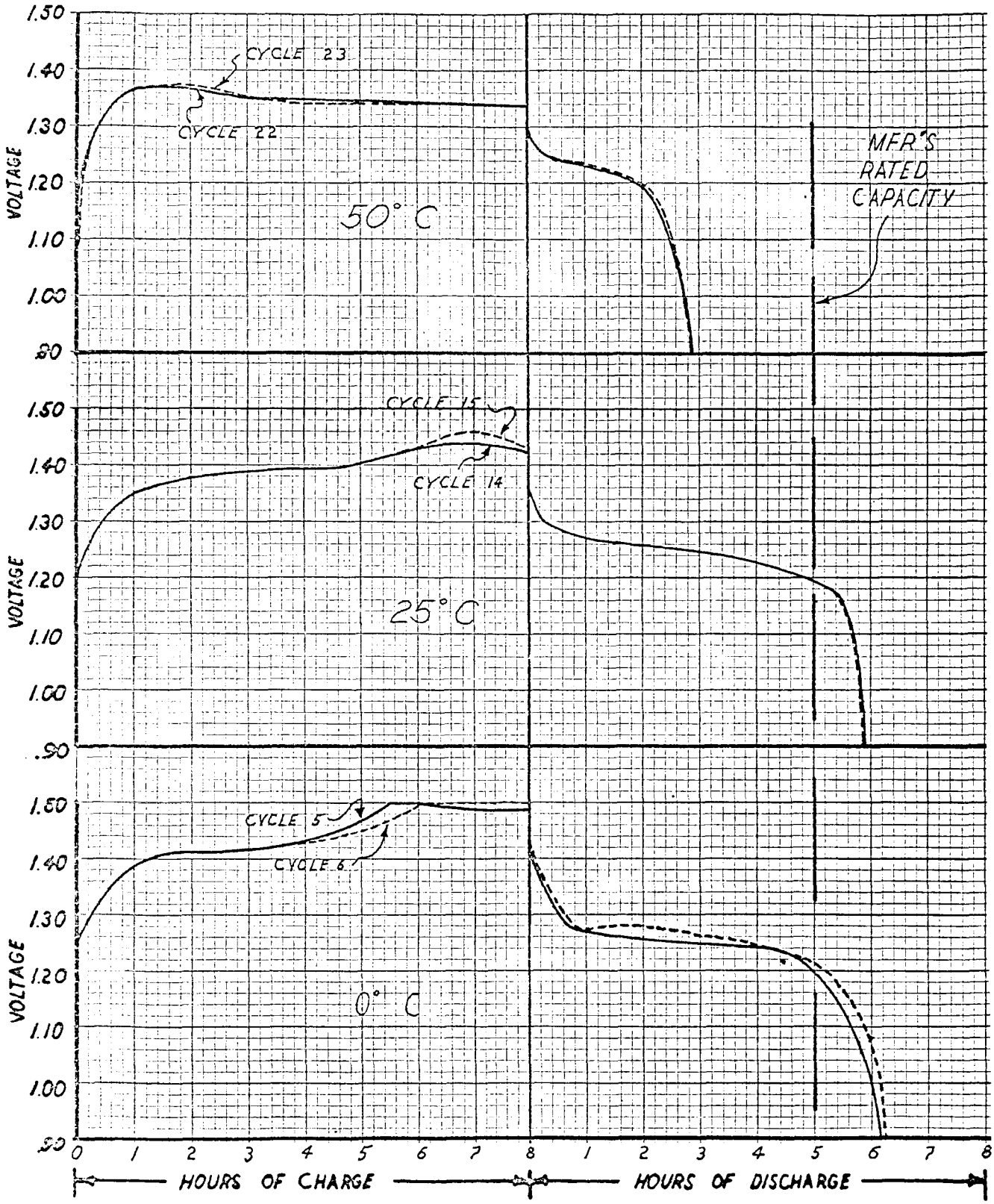
G.E. 12 A.H. Cell No. 33-24 NAD CRANE CAPACITY 15.60 A.H.
CHARGE CURRENT 1.2 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 6.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 9



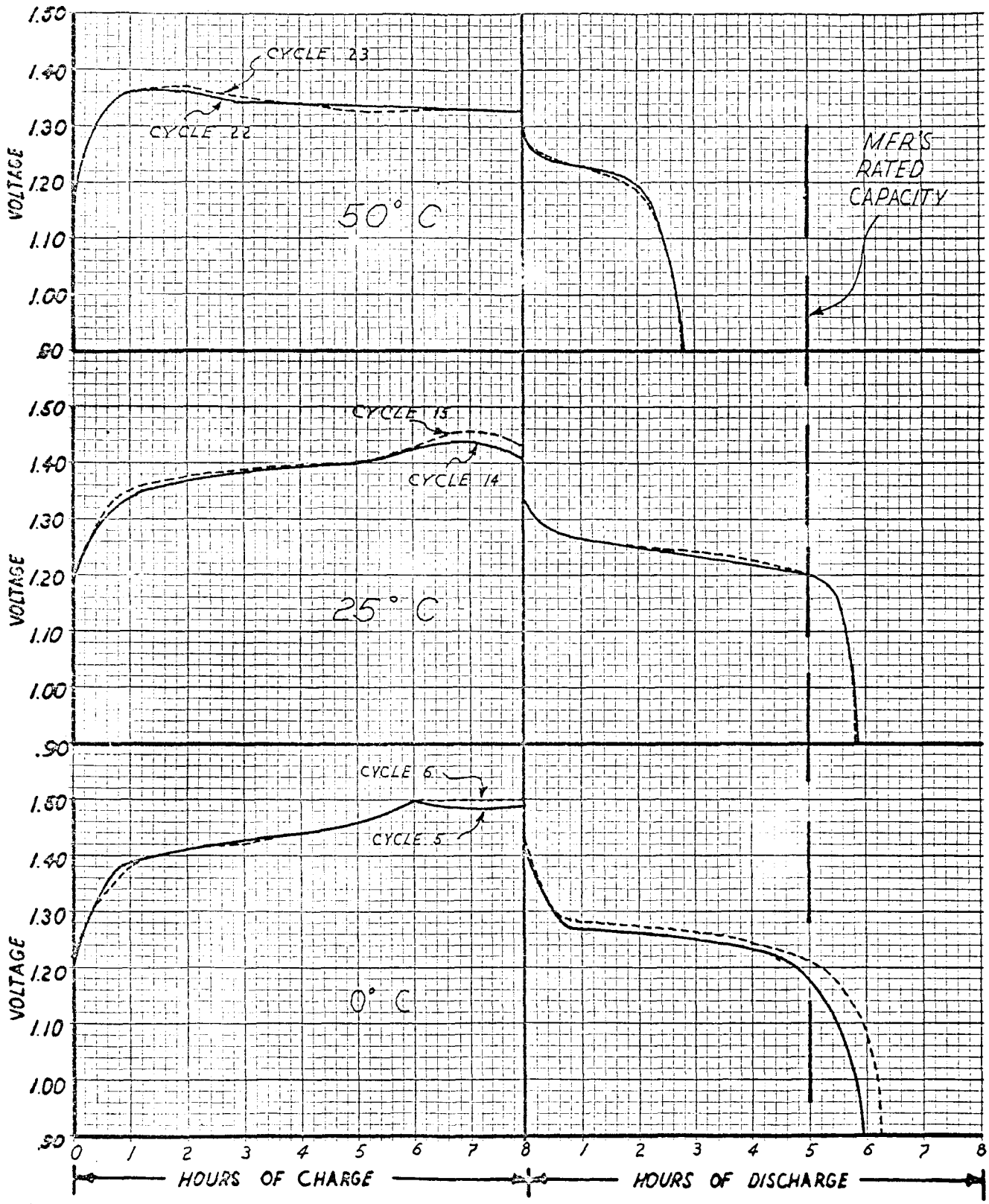
G.E. 12 A.H. Cell No. 33-29 NAD CRANE CAPACITY 15.60 A.H.
CHARGE CURRENT 1.2 A. (C/10), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 6.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 10



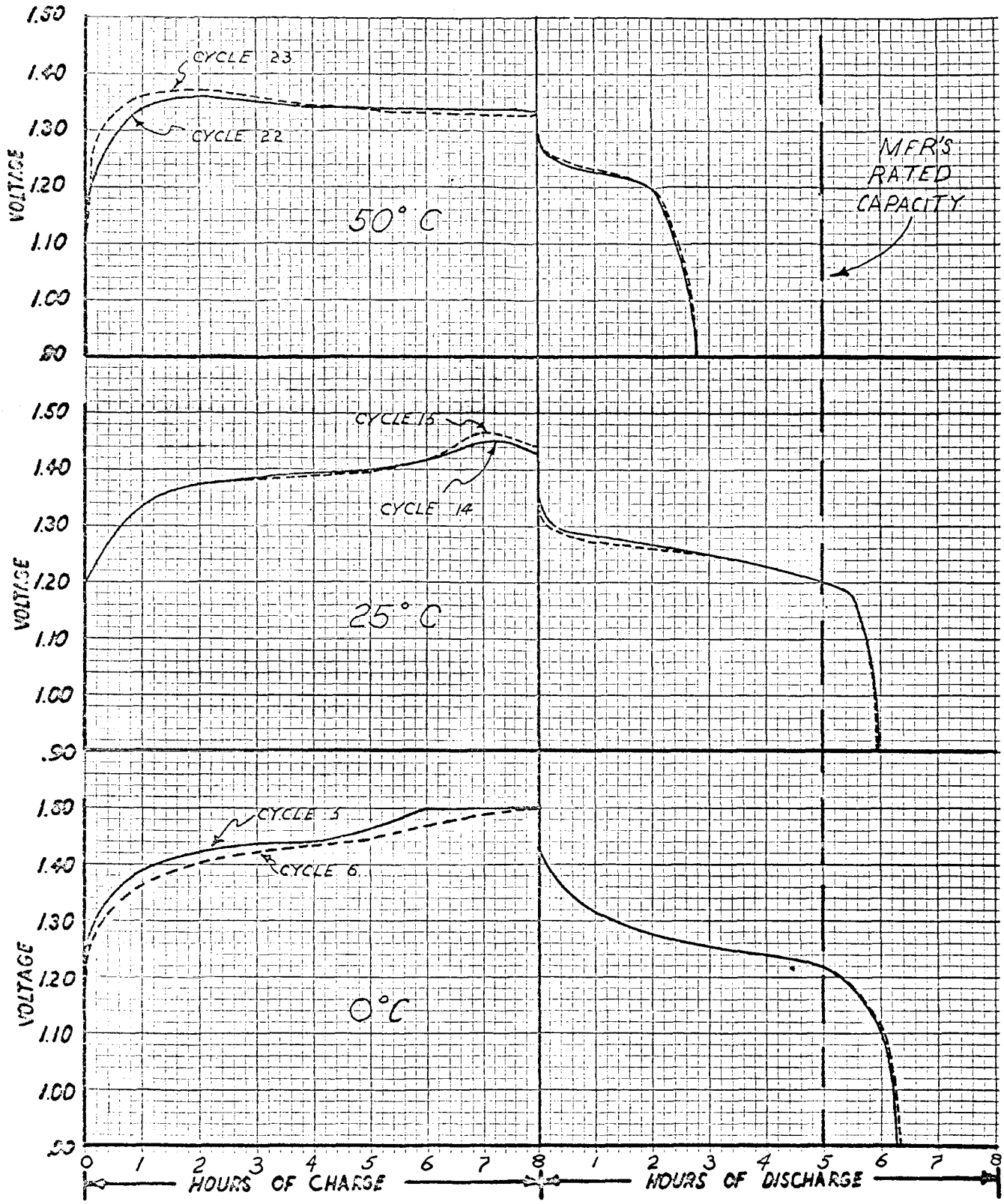
G.E. 12 A.H. CELL NO. 416 NAD CRANE CAPACITY 12.90 A.H.
CHARGE CURRENT 2.4 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 2.4 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 11



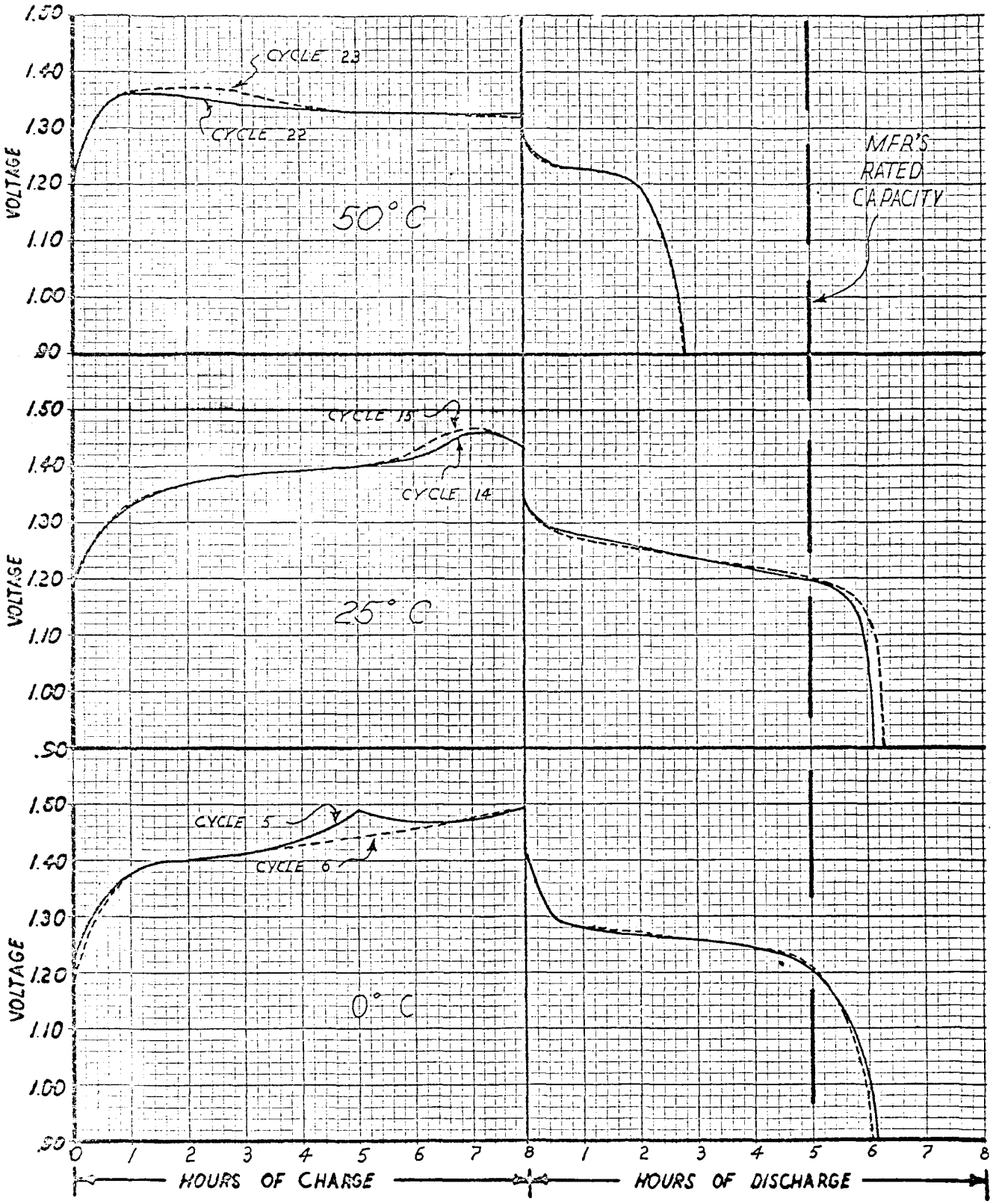
G.E. 12 A.H. CELL No. 420 NAD CRANE CAPACITY 12.90 A.H.
CHARGE CURRENT 2.4 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 2.4 A. (C/5), CUTOFF VOLTAGE 0.9 V.

RE 12



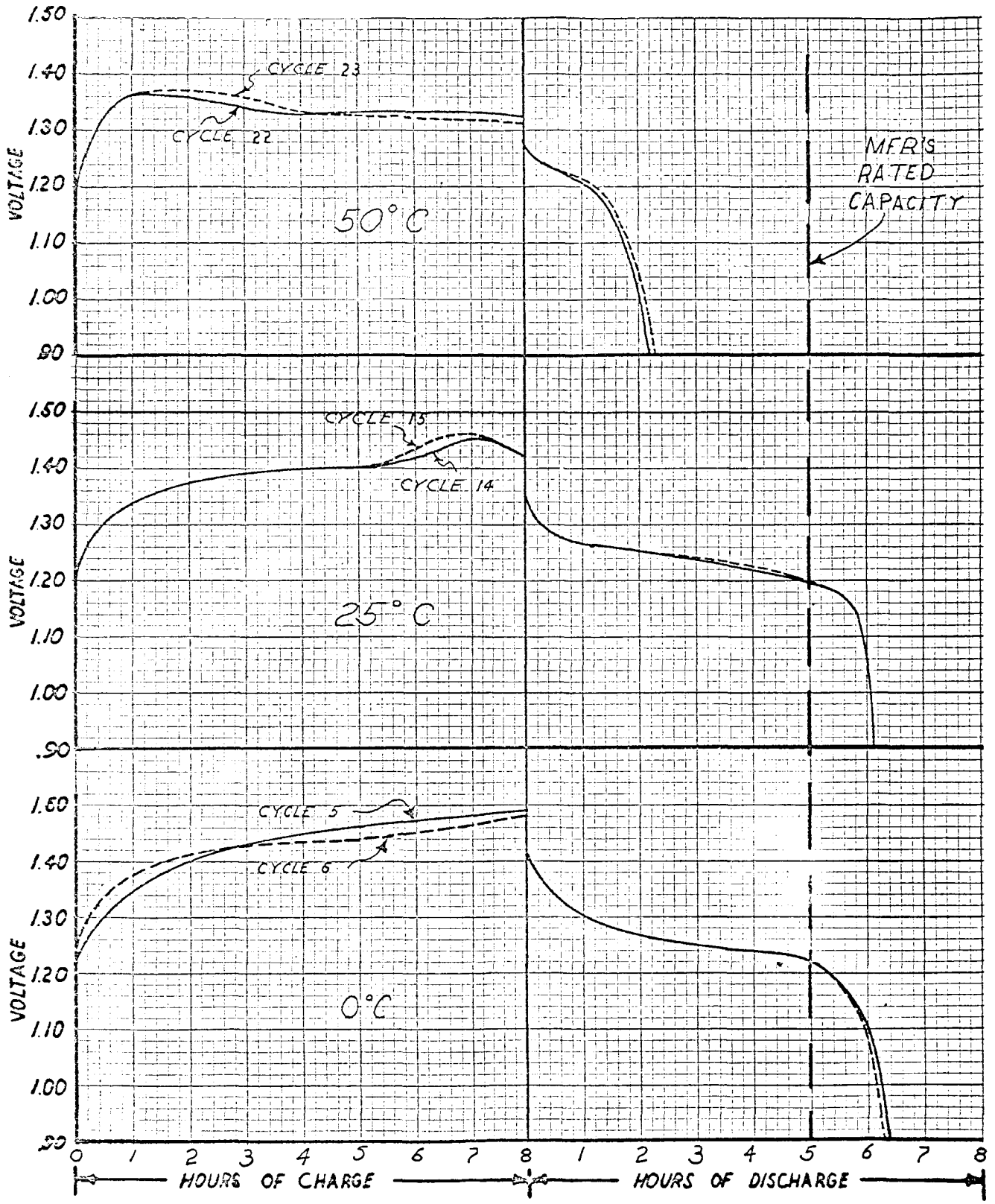
G.E. 12 A.H. CELL NO. 11-7 NAO CRANE CAPACITY 14.52 A.H.
CHARGE CURRENT 2.4 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 2.4 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 13

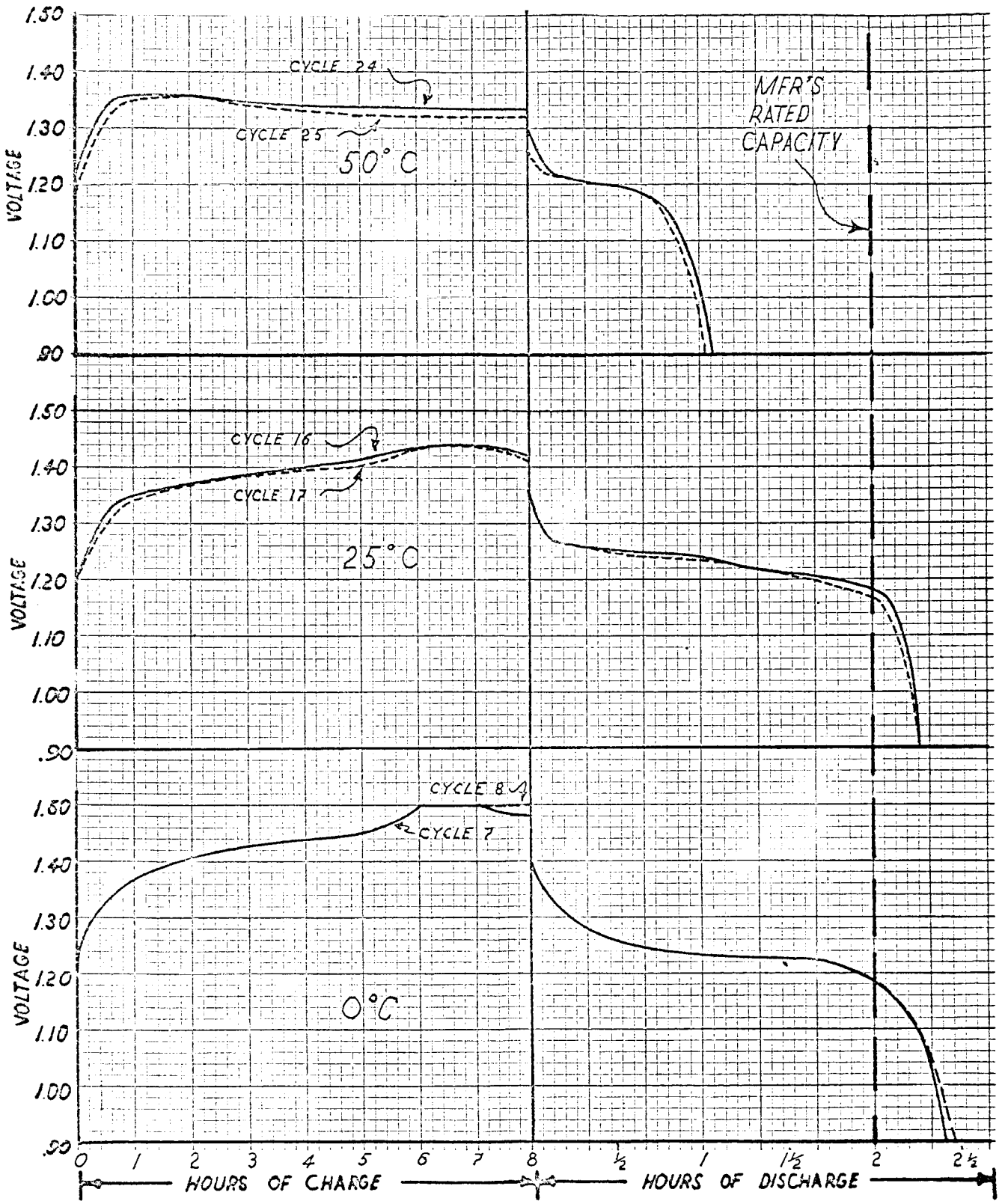


G.E. 12 A.H. CELL No. 33-24 NAD CRANE CAPACITY 15.60 A.H.
CHARGE CURRENT 2.4 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 2.4 A. (C/5), CUTOFF VOLTAGE 0.9 V.

FIGURE 14

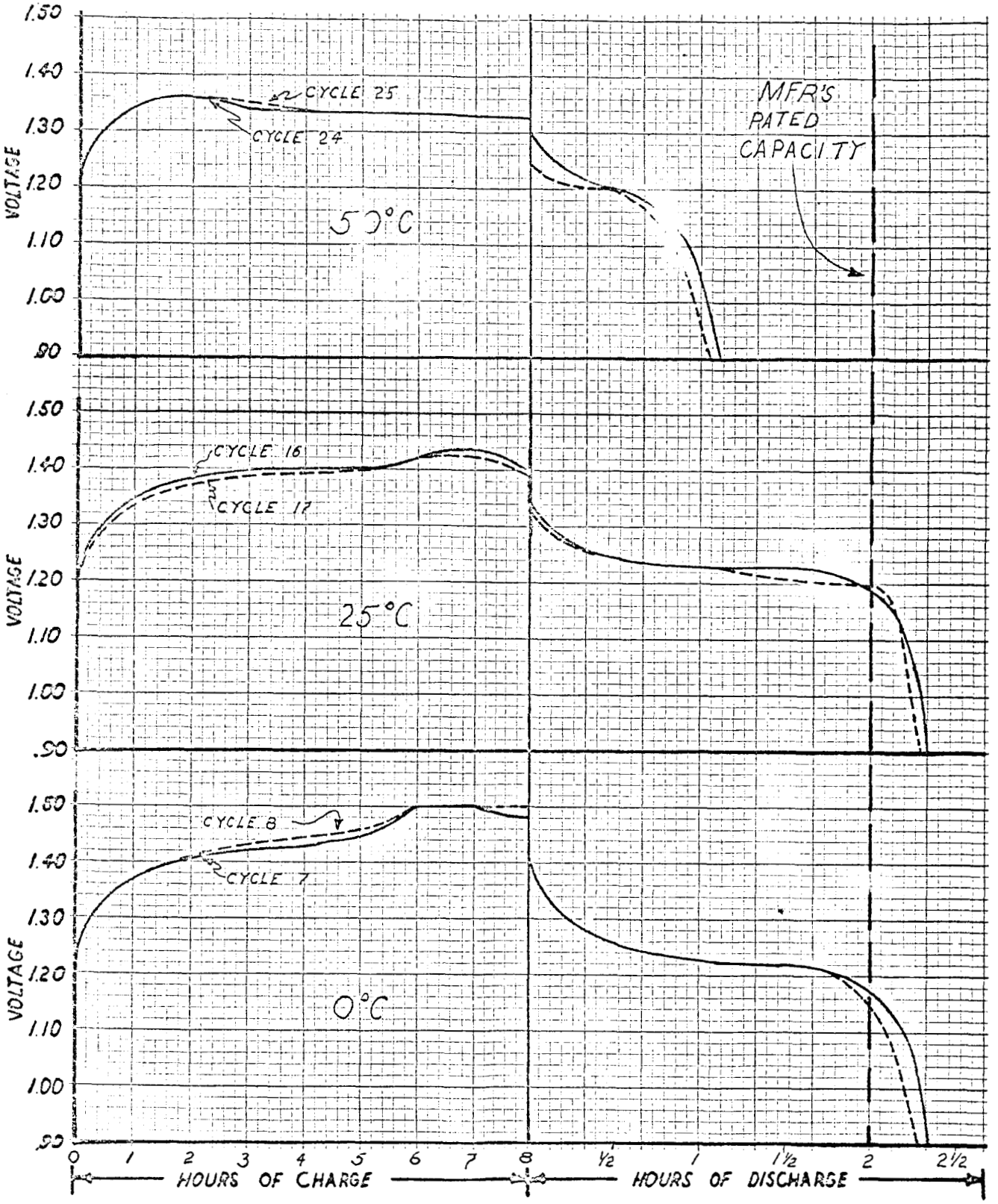


G.E. 12 A.H. CELL No. 33-29 NAD CRANE CAPACITY 15.60 A.H.
CHARGE CURRENT 2.4 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 2.4 A. (C/5), CUTOFF VOLTAGE 0.9 V.

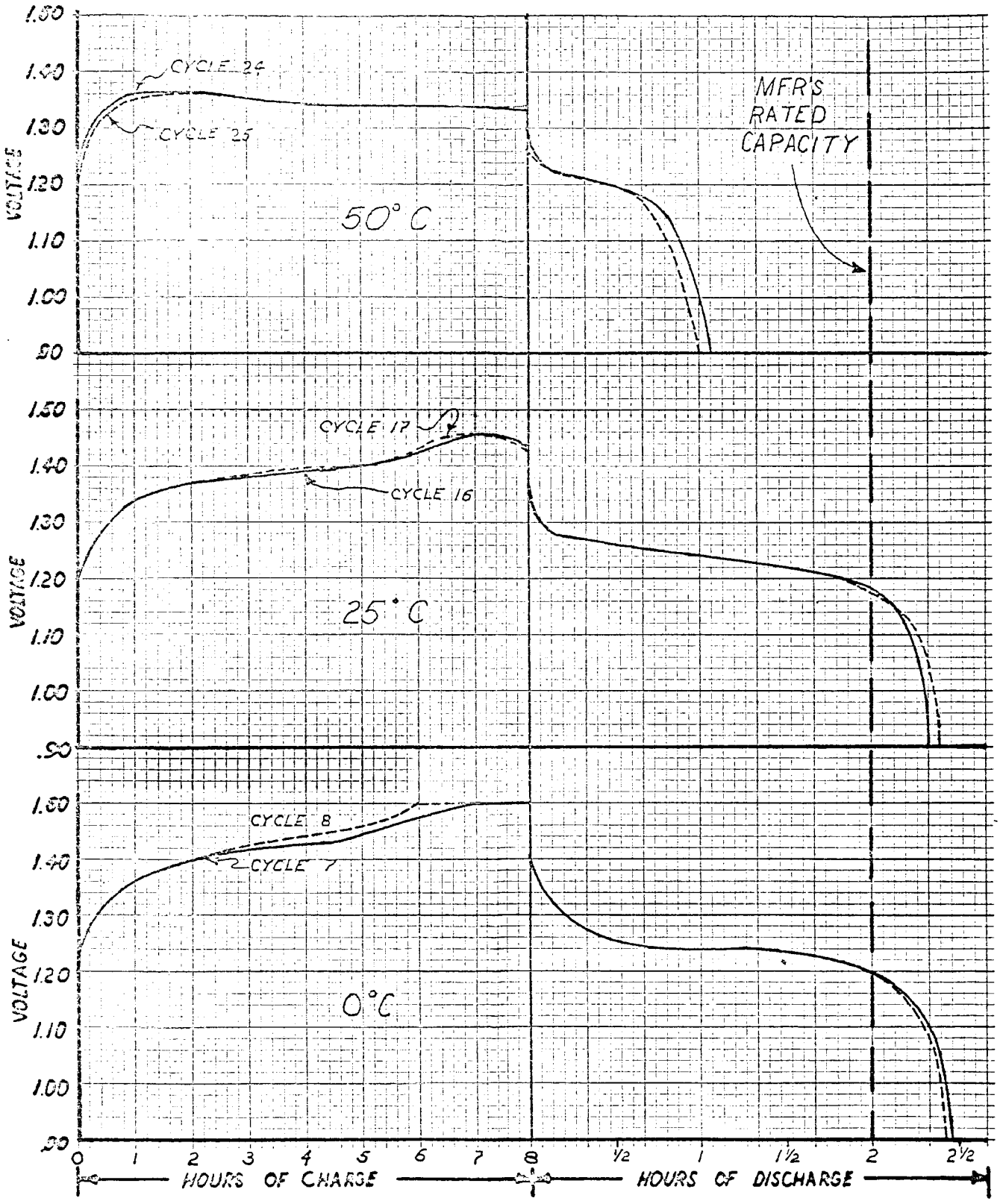


G.E. 12 A.H. CELL No. 4/6 NAD CRANE CAPACITY 12.90 A.H.
CHARGE CURRENT 2.4 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 6.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 16

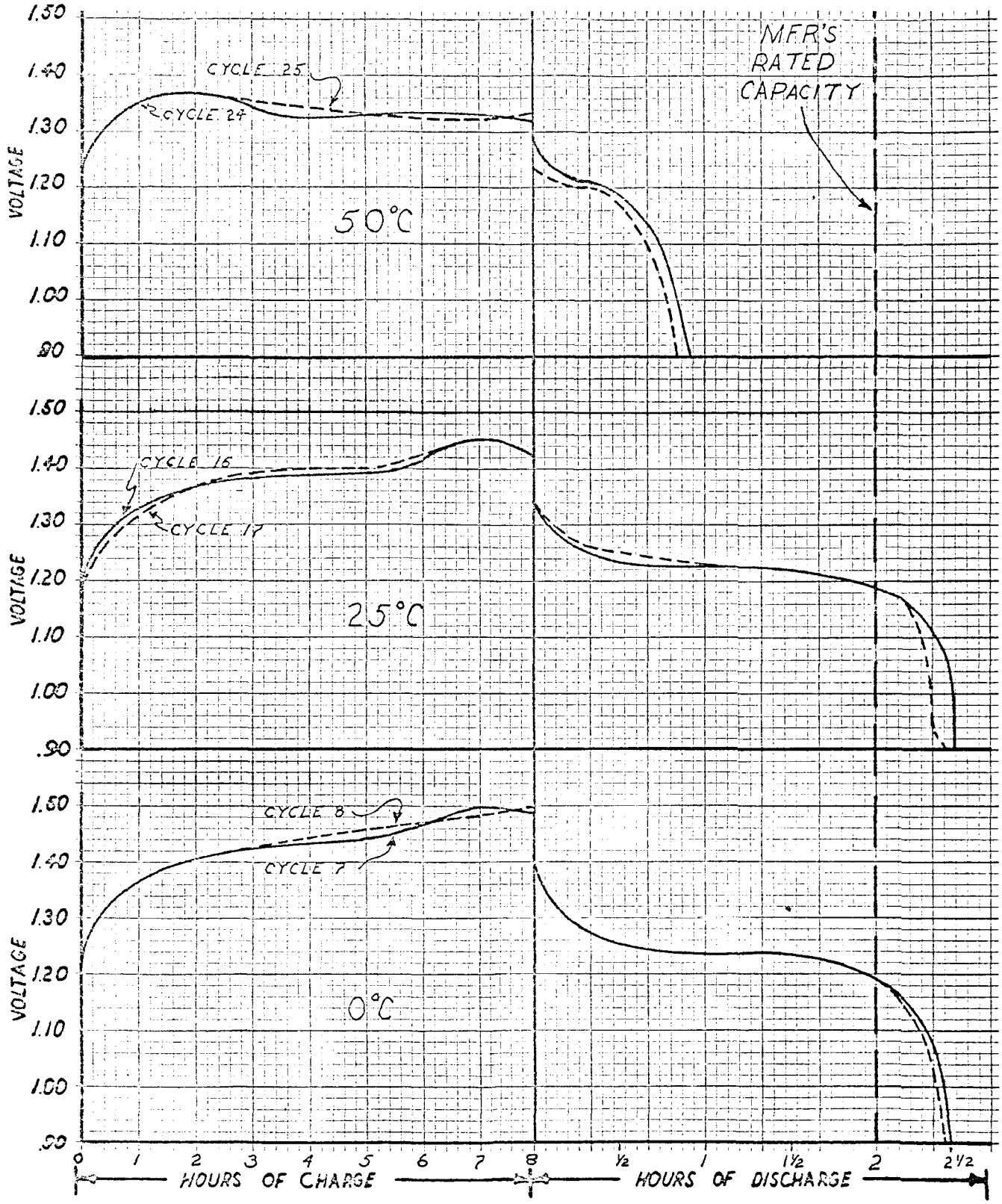


G.E. 12 A.H. CELL NO. 420 NAD CRANE CAPACITY 12.90 A.H.
CHARGE CURRENT 2.4 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 6.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.



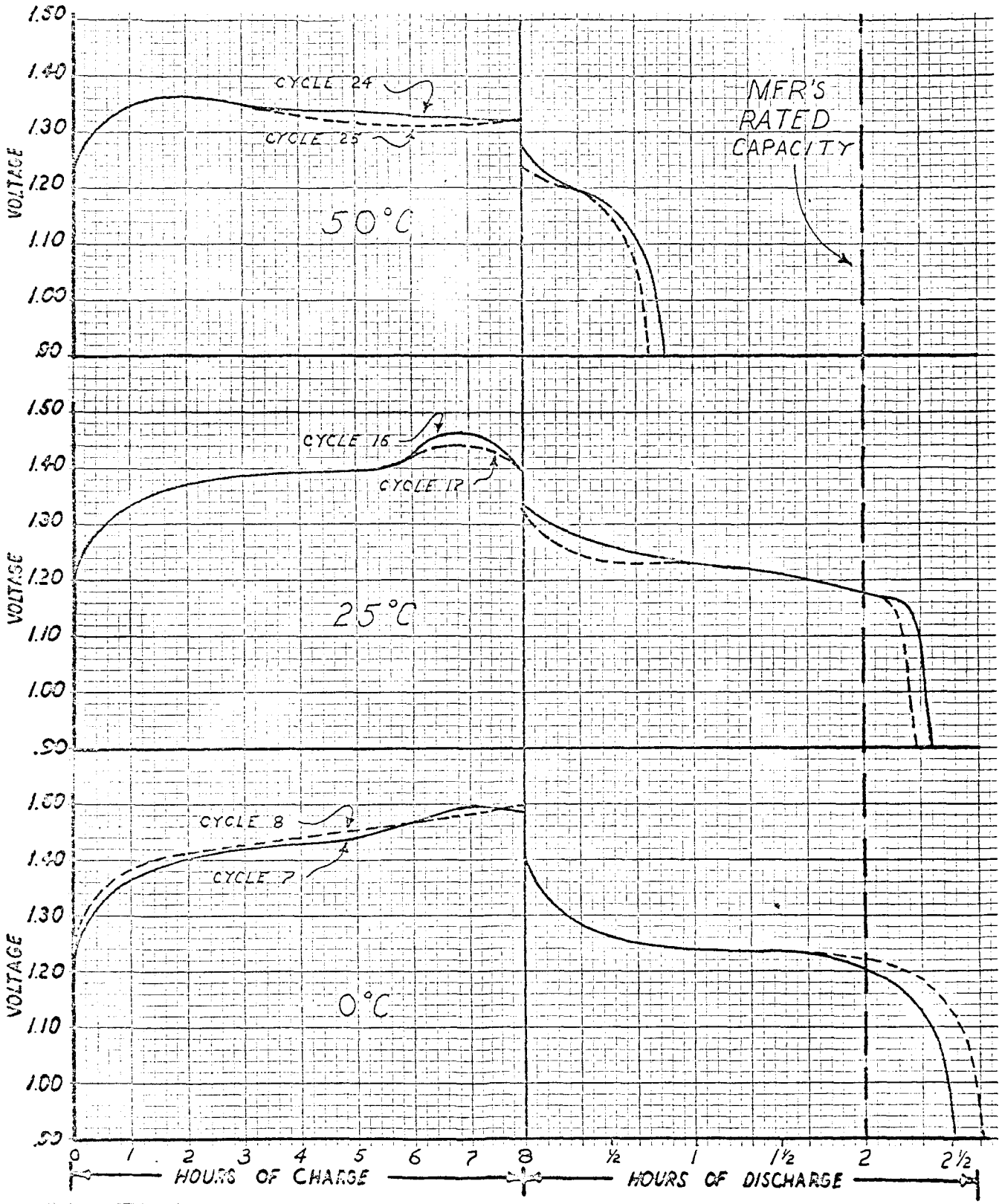
G.E. 12 A.H. Cell No. 11-7 NAD CRANE CAPACITY 14.52 A.H.
CHARGE CURRENT 2.4 A. (C/5), VOLTAGE LIMITED TO 1.60 V. PER CELL
DISCHARGE CURRENT 6.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

FIGURE 18

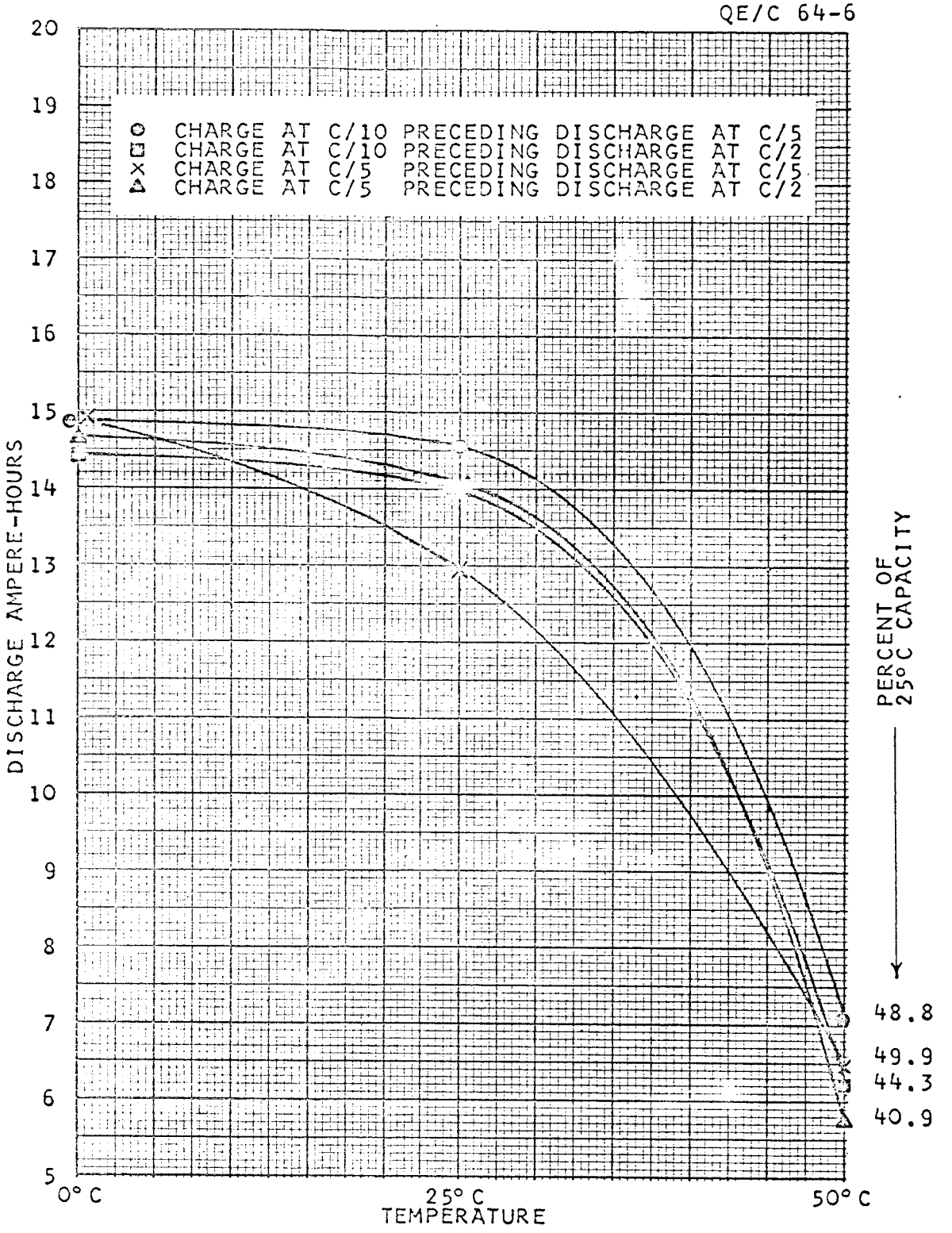


G.E. 12 A.H. CELL NO. 33-24 NAD CRANE CAPACITY 15.60 A.H.
CHARGE CURRENT 2.4 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 6.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

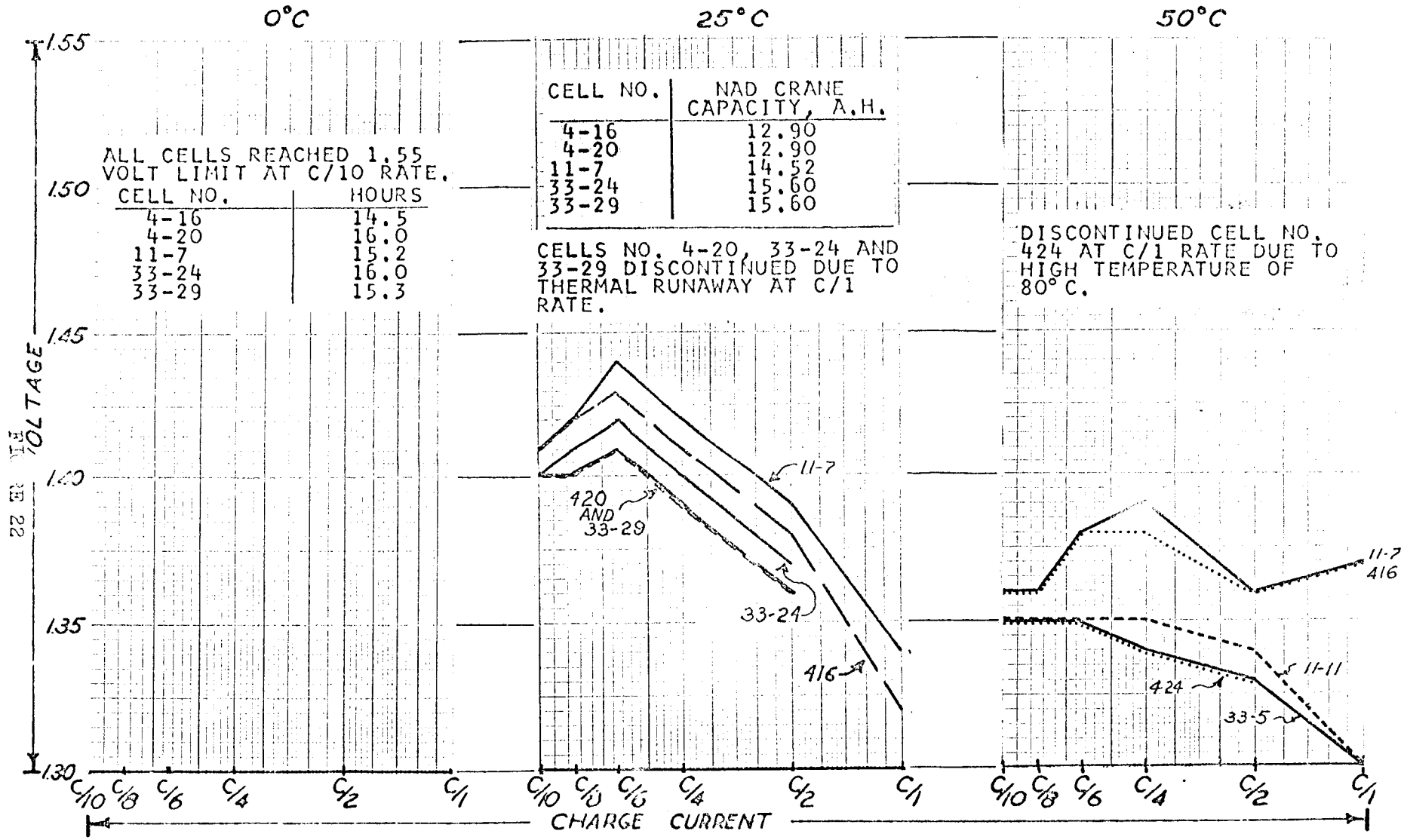
FIGURE 19



G.E. 12 A.H. CELL No. 33-29 NAD CRANE CAPACITY 15.60 A.H.
CHARGE CURRENT 2.4 A. (C/5), VOLTAGE LIMITED TO 1.50 V. PER CELL
DISCHARGE CURRENT 6.0 A. (C/2), CUTOFF VOLTAGE 0.9 V.

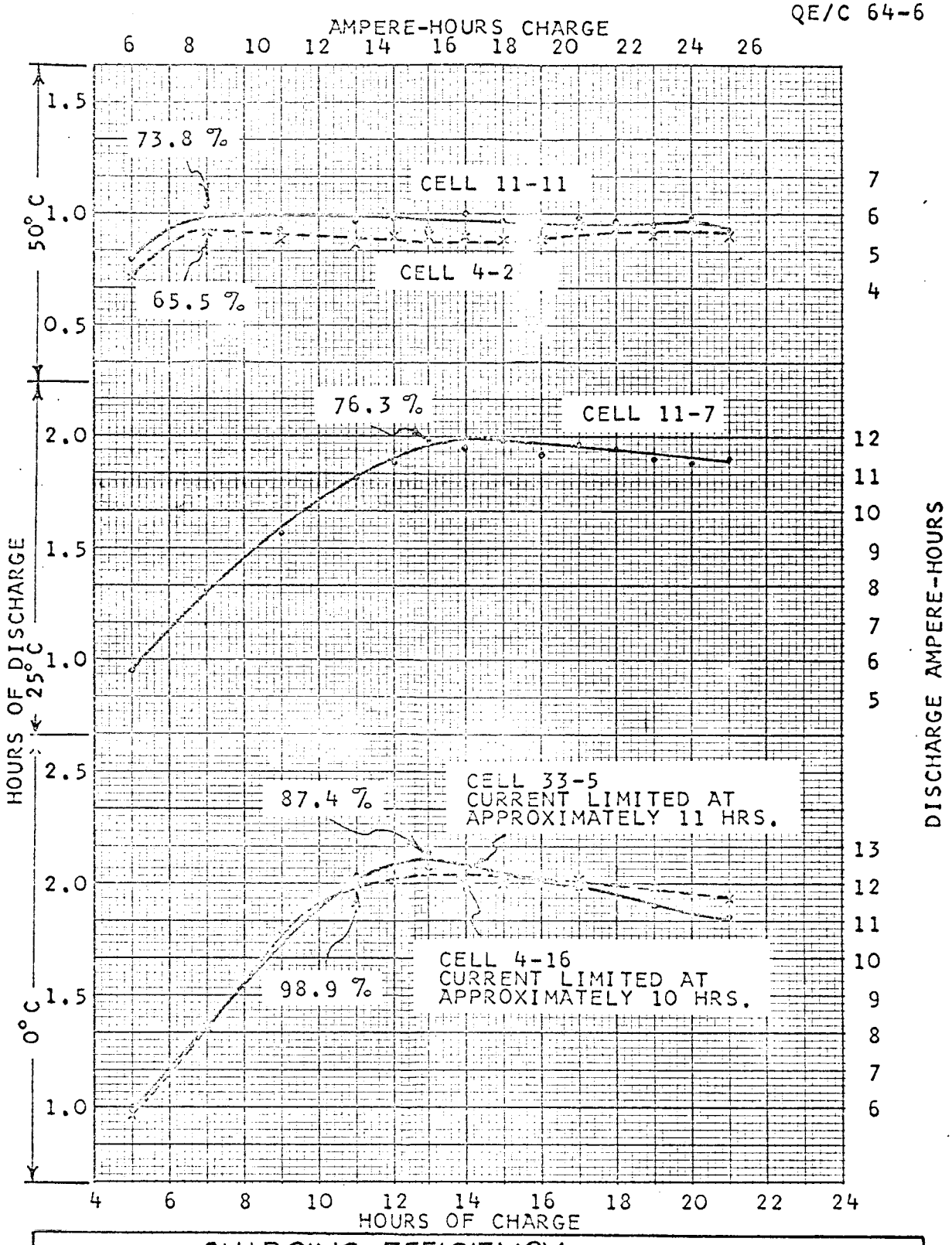


G.E. 12 A.H.
AVERAGE CELL OUTPUT VS TEMPERATURE
(FROM FIGURES 1 THROUGH 20)



G. E. 12 A. H
OVERCHARGE CHARACTERISTICS

QE/C 64-6



CHARGING EFFICIENCY

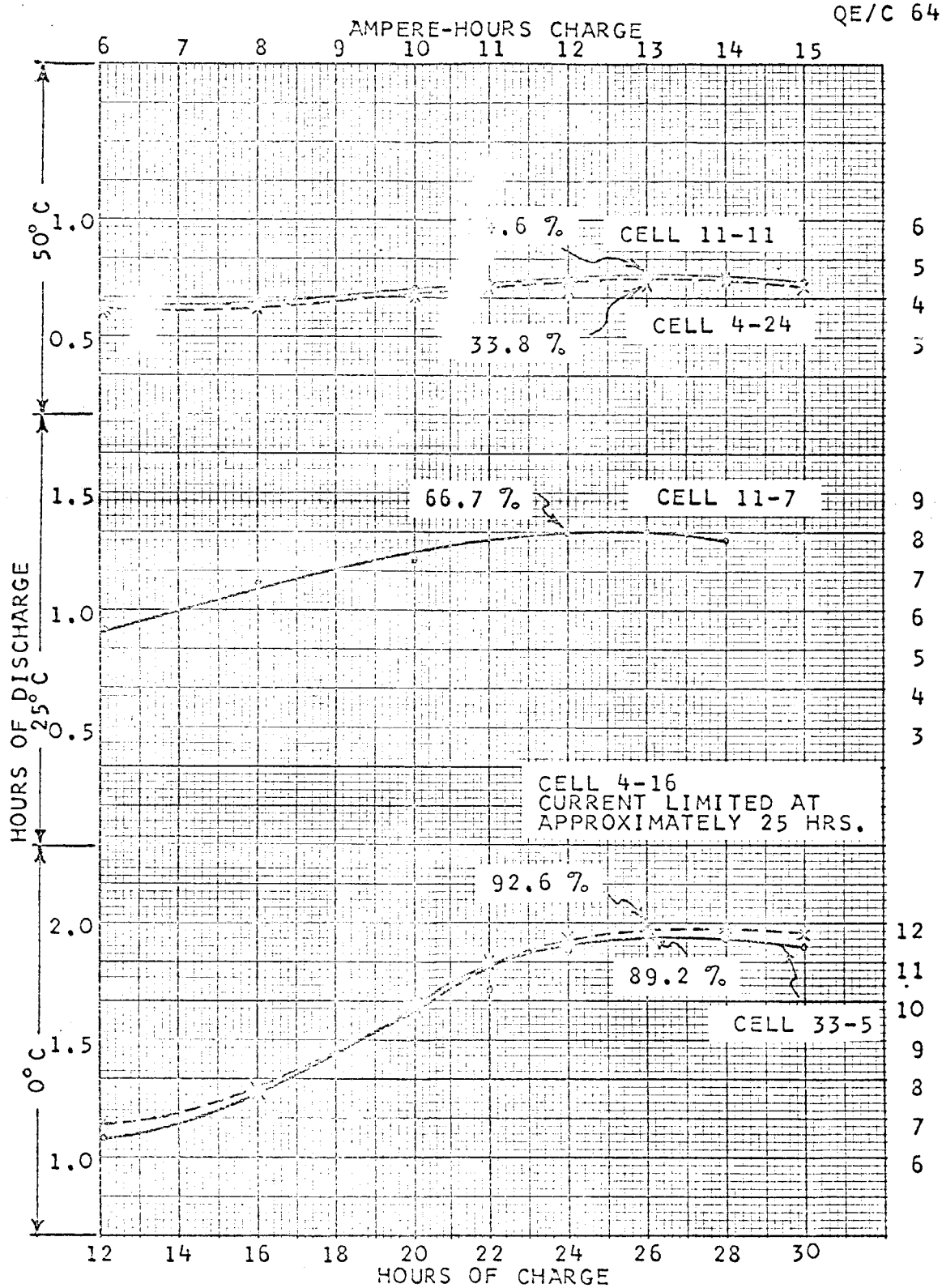
G.E. 12 A.H.

CHARGE CURRENT 1.20 A. - C/10
VOLTAGE LIMITED TO 1.50 V.

DISCHARGE CURRENT 6.0 A. - C/2
CUTOFF VOLTAGE 1.0 V.

CELL NO.	NAD CRANE CAPACITY, A.H.
33-5	15.90
11-11	14.82
11-7	14.52
4-24	13.08
4-16	12.90

FIGURE 23



CHARGING EFFICIENCY

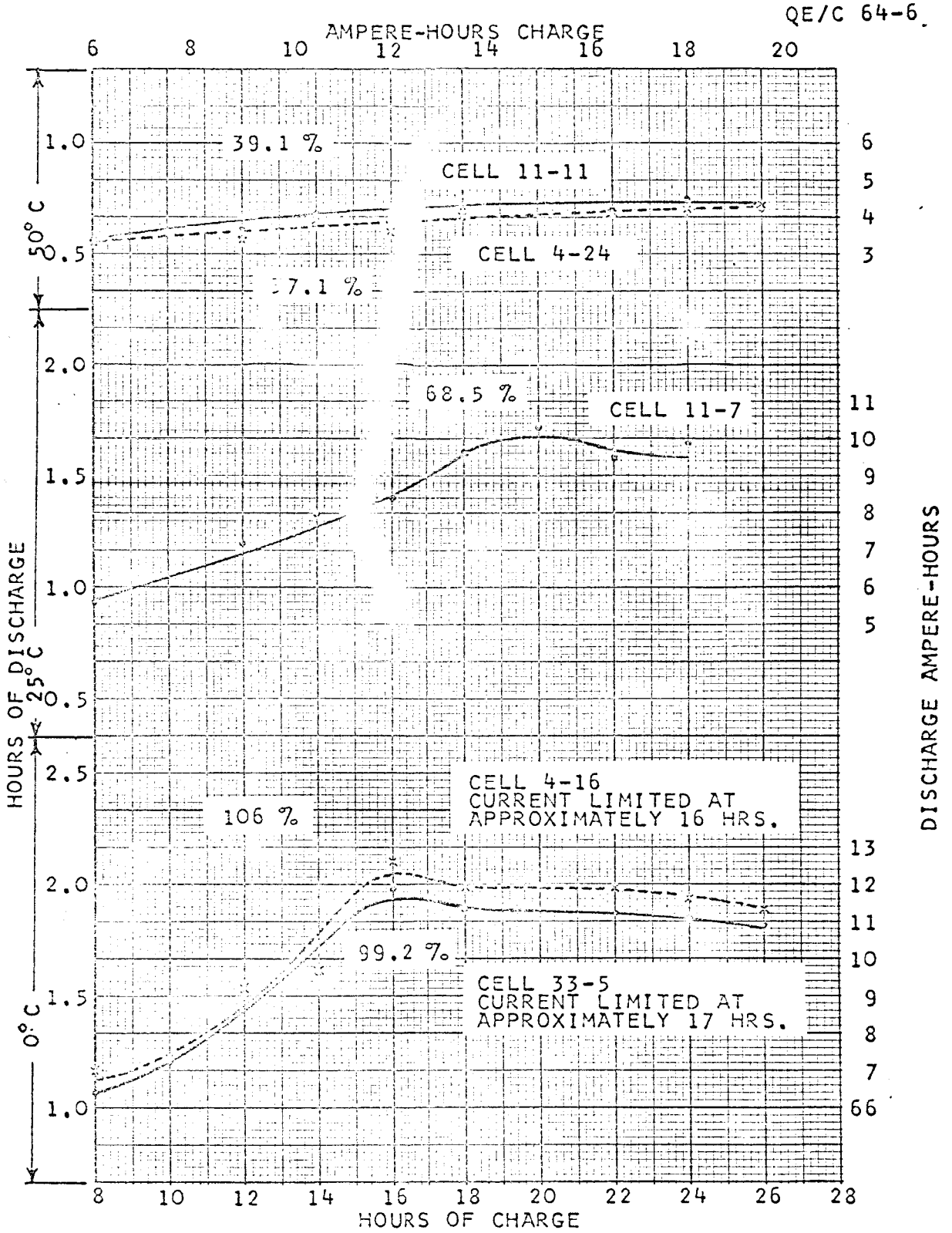
G.E. 12 A.H.

CHARGE CURRENT 0.50 A. - C/24
VOLTAGE LIMITED TO 1.50 V.

DISCHARGE CURRENT 6.0 A. - C/2
CUTOFF VOLTAGE 1.0 V.

CELL NO.	NAD CRANE CAPACITY, A.H.
33-5	15.90
11-11	14.82
11-7	14.52
4-24	13.08
4-16	12.90

FIGURE 24



CHARGING EFFICIENCY

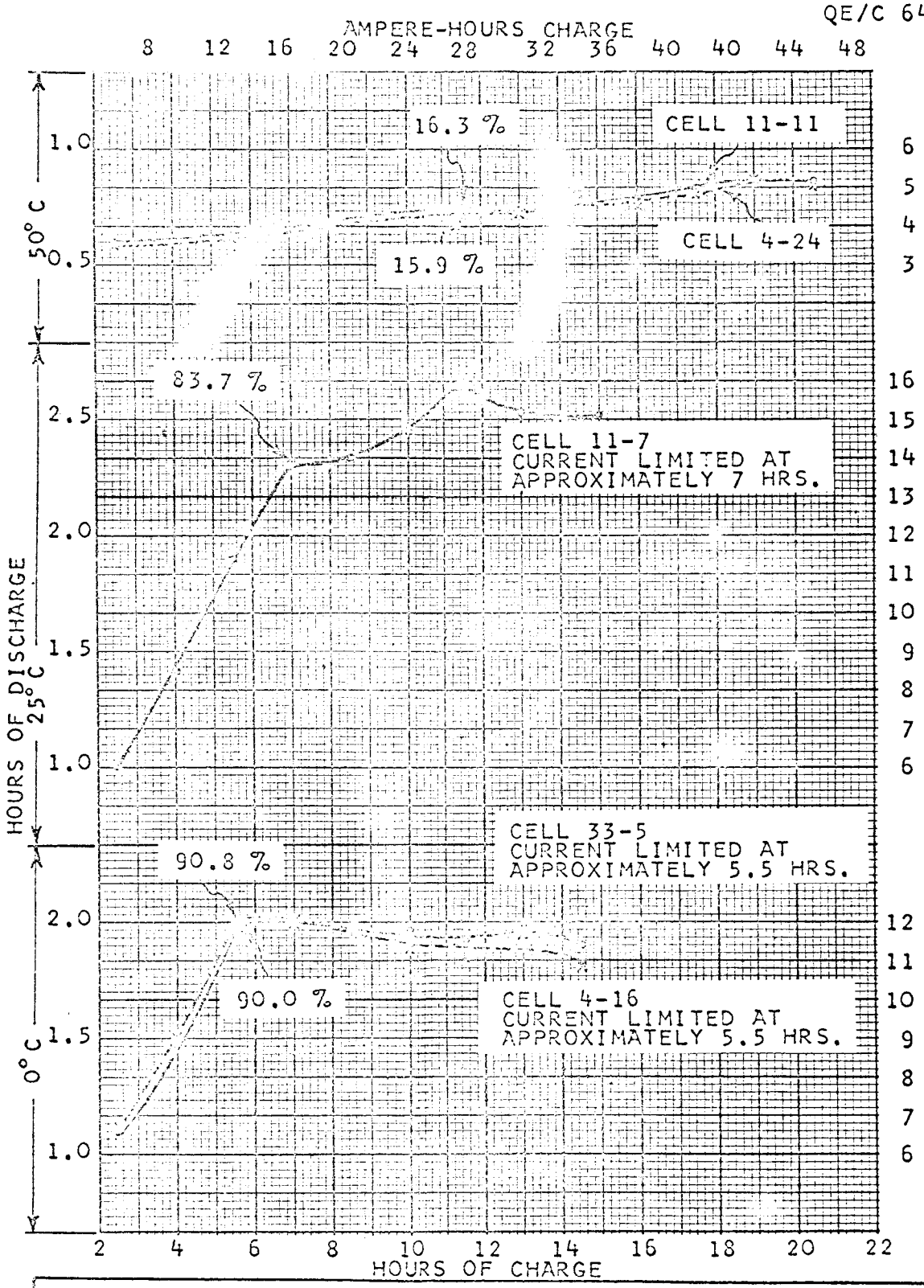
G.E. 12 A.H.

CHARGE CURRENT 0.75 A. - C/16
VOLTAGE LIMITED TO 1.50 V.

DISCHARGE CURRENT 6.0 A. - C/2
CUTOFF VOLTAGE 1.0 V.

CELL NO.	NAD CRANE CAPACITY, A.H.
33-5	15.90
11-11	14.82
11-7	14.52
4-24	13.08
4-16	12.90

FIGURE 2



CHARGING EFFICIENCY

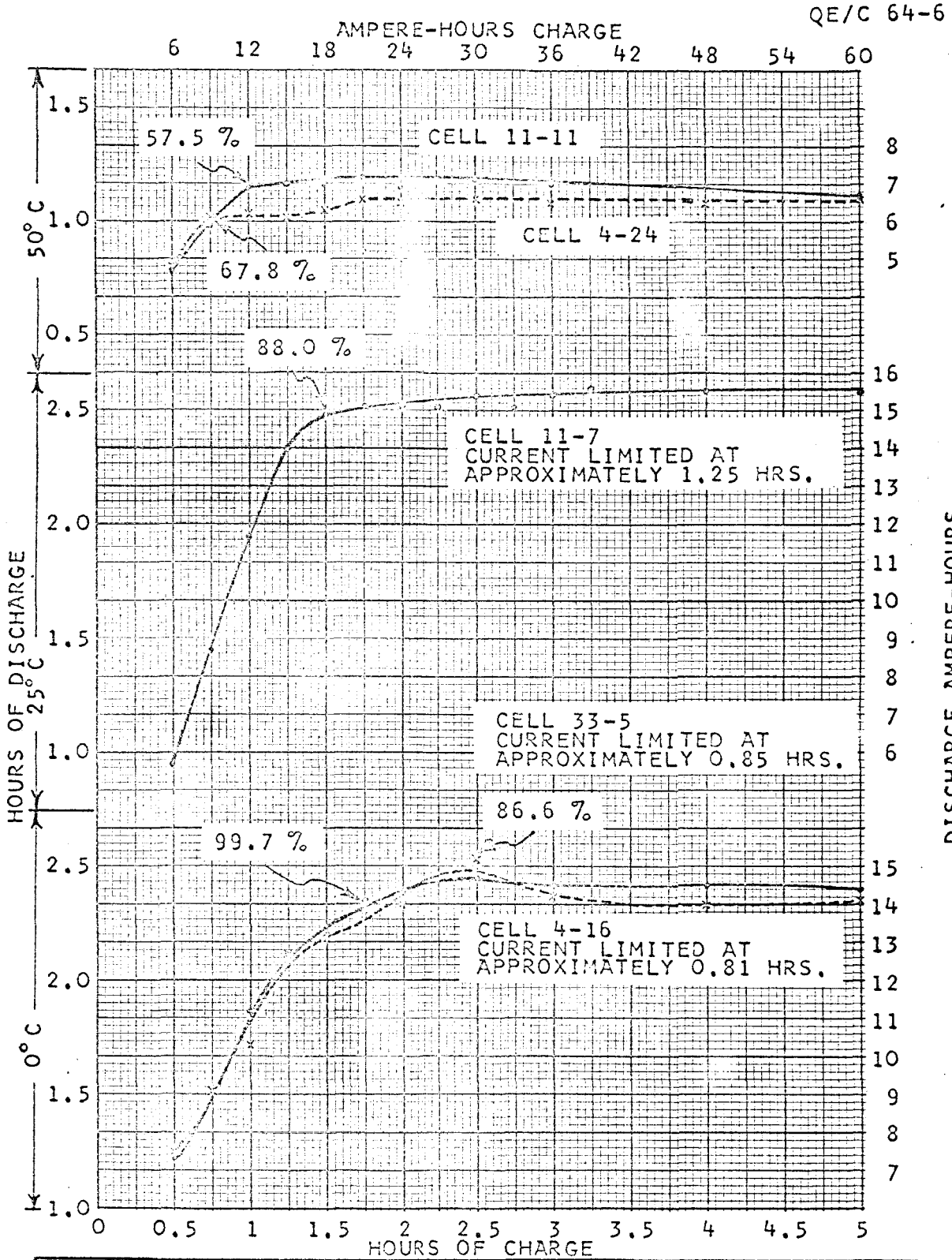
G.E. 12 A.H.

CHARGE CURRENT 2.40 A. - C/5
VOLTAGE LIMITED TO 1.50 V.

DISCHARGE CURRENT 6.0 A. - C/2
CUTOFF VOLTAGE 1.0 V.

CELL NO.	NAD CRANE CAPACITY, A.H.
33-5	15.90
11-11	14.82
11-7	14.52
4-24	13.08
4-16	12.90

FIGURE 26



CHARGING EFFICIENCY

G.E. 12 A.H.

CHARGE CURRENT 12.0 A. - C/1
VOLTAGE LIMITED TO 1.50 V.

DISCHARGE CURRENT 6.0 A. - C/2
CUTOFF VOLTAGE 1.0 V.

CELL NO.	NAD CRANE CAPACITY, A.H.
33-5	15.90
11-11	14.82
11-7	14.52
4-24	13.08
4-16	12.90

FIG. 27

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